4 ENGINEERING

4.1 Engineering Components

1) General

(1) Civil/Structural/Building Services

It is envisaged that the scope of engineering works included construction of the basic infrastructure for the UMRT Line 2 final system as part of the civil and structural works program for the project. This will include but not limited to:

(i) Civil works including site formation, road & utility diversions;
(ii) Structural works including guideway viaduct, at grade track and tunnel sections including portals and ventilation requirements;
(iii) Stations & walkways (elevated or underground);
(iv) Depot buildings & facilities;
(v) Administration building, Operations Control Centre & ancillary buildings including substations, ventilation buildings;
(vi) All Building Services including fire protection, drainage & plumbing; and
(vii) Architectural and builderswork finishes including landscaping.

(2) Rail Systems

The final project would also include all rail systems such as:

(i) Rolling stock/vehicle supply, commissioning and installation;
(ii) Signaling, Automatic train protection (ATP);
(iii) Automatic train control (ATC), option;
(iv) Communications, telecoms, CCTV;
(v) Traction power including uninterrupted power supply (UPS);
(vi) Standby generators;
(vii) Tunnel ventilation & fire protection systems
(viii) SCADA;
(ix) Automatic Fare Collection (AFC);
(x) Platform Screen Doors (PSD);
(xi) Operations Control and monitoring system;
(xii) Maintenance including depot equipment;
(xiii) UMRT Line 2 System testing and commissioning;
(xiv) Operations of the UMRT Line 2 system maintenance.

(3) Interface Management

The interface management between the rail systems and the transit infrastructure would be carried out by the selected bidder and his management team who has experience in program management for similar major rail system projects.

It will be the selected bidder and his management team's joint responsibility to identify and manage the precise interface between the civil/structural/architectural/E&M and the rail systems.

In addition, the selected bidder will be expected to coordinate his works with other major infrastructure projects along the transport corridor, details of which are outlined in this submission.

The interface management must be specified in more detail with the selected bidder early in the implementation stage of the project, details of which should be included in the tender submissions of the selected bidder.

(4) Civil Works

The civil works advance contract will include but not limited to:

(i) Site formation, land clearance, fencing and security;
(ii) Utilities diversions/connections;
(iii) Water/electricity/drainage (foul & storm)/telecoms;
(iv) Road works (road widening, temporary diversions, re-provisioning of footbridges, u-turn slots, transport interchanges);
(v) Street furniture/lighting/signage and the re-provisioning of existing traffic management schemes; and
(vi) Work sites, storage areas and the establishment of the UMRT Line 2 project offices.

The successful bidder will be responsible for the coordination with all major highway civil works planned along the UMRT Line 2 transit corridor. It is planned to include any special requirements for the UMRT Line 2 system in this initial phase including station and depot sites, power and telecoms, utilities facilities and associated roadways and walkways leading to the station sites.

(5) Structural Works

The major structural elements will also be constructed as part of the development of the UMRT Line 2 system including the viaduct, at-grade & tunnel guideway, stations, depot & stabling area, OCC and ancillary buildings such as substations required to operate the UMRT Line 2 system.

The successful bidder would be expected to verify this preliminary information and incorporate/coordinate the interfaces with the respective authorities and utilities.

2) Viaduct Structures

(1) Guideway Structures

The elevated viaduct section is expected to be from Thai Phu to Hai Boi in the north and from Thoung Dinh to Ha Dong in the south.

The viaduct guideway structure will include:

(i) Foundations, columns, crosshead, viaduct;
(ii) Single/ double track sections;
(iii) Overrun tracks;
(iv) Crossover tracks; and
(v) Depot access tracks.

It is envisaged that the design will generally be in accordance with the American Association of State Highway and Transportation Officials (AASHTO) standard or similar internationally accepted standard or equivalent Japanese standard.

(2) Substructure

Initial soil site investigation information is included in this report. In order to minimize the effect of differential settlement and avoid significant cracking occurring in the viaduct structure, it is expected that a pile foundation will be necessary to support the viaduct construction.

The foundations will therefore be either bored or driven piles depending on the most efficient piling system and will either be single large-diameter concrete piles or groups of piles with a connecting pile cap. This will largely depend on the design loadings from the rolling stock and viaduct structure.

(3) Columns & Crosshead

The foundation will support columns and a crosshead which will be in either concrete or steel to support the viaduct structure.

The height of the column will be between eight and 19 meters above existing ground level depending on the alignment, vertical geometry and the station locations.

(4) Single/Double Track Viaduct Deck Structure

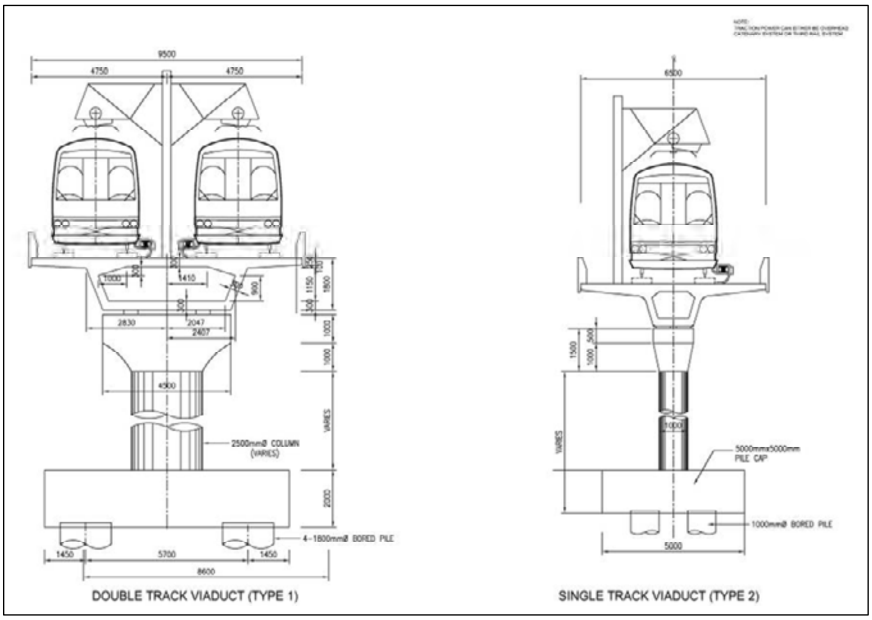
The guideway structure will be either single or twin track. Generally the alignment will be twin track: however, certain sections may be twin single-track viaducts as determined during the next stage of development of the UMRT Line 2 schematic plan.

The viaduct structure will be a pre-stressed concrete beam, box girder, continuous beams or alternatively a lightweight steel truss framework.

Typical spans of 30-35 meters will be adopted with a maximum span not to exceed 45 meters where due to site constraints such as road crossings and rolling stock loadings, the standard bridge spans cannot be used.

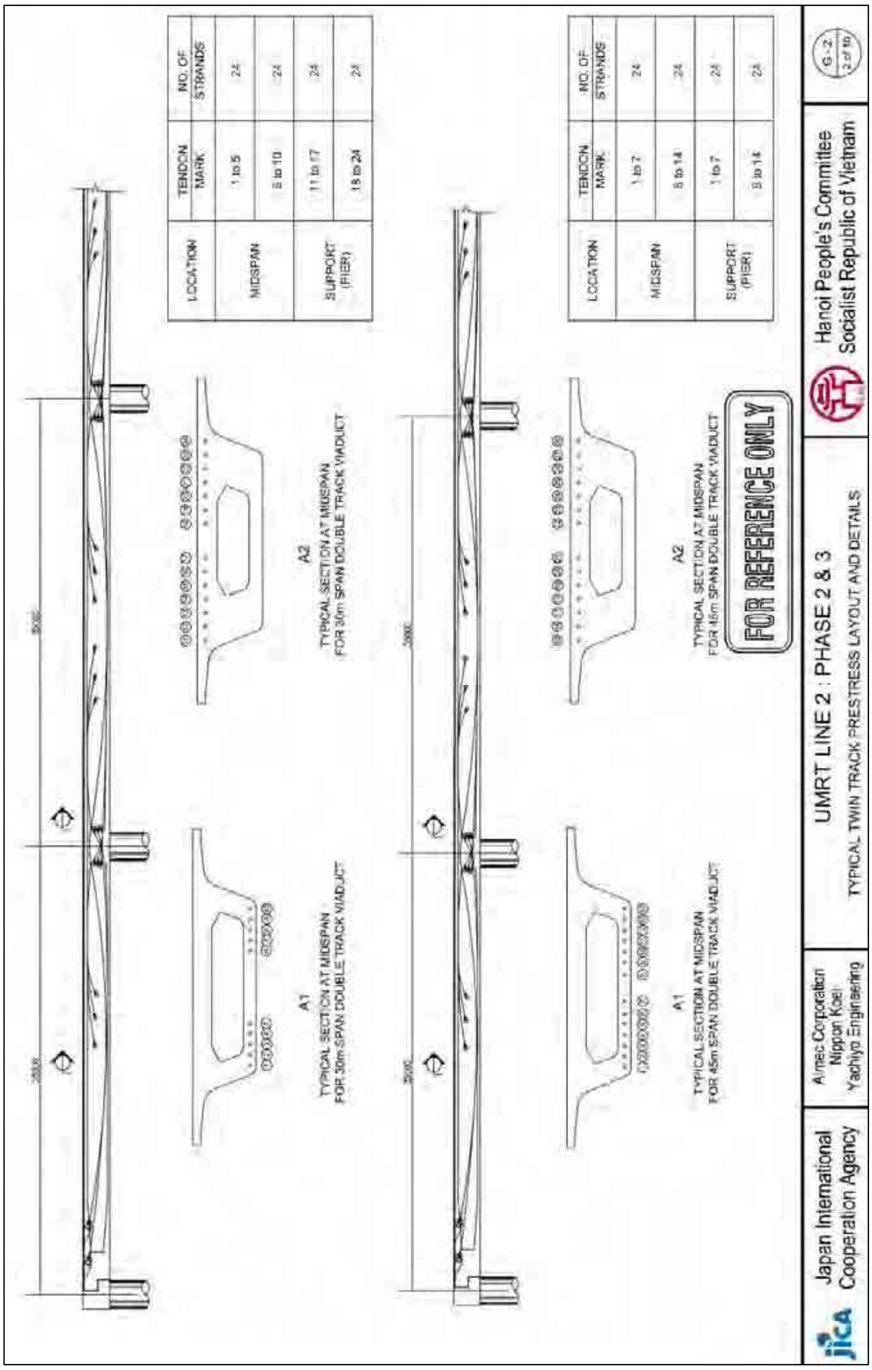
If a bridge crossing of the Red River is proposed, special consideration will be given to long span bridge construction including loadings associated with impact from river craft (up to 600dwt).

Figure 4.1.1 Typical Viaduct Sections



Source: HAIDEP Study Team

Figure 4.1.2 Typical Twin Track Prestress Layout and Details



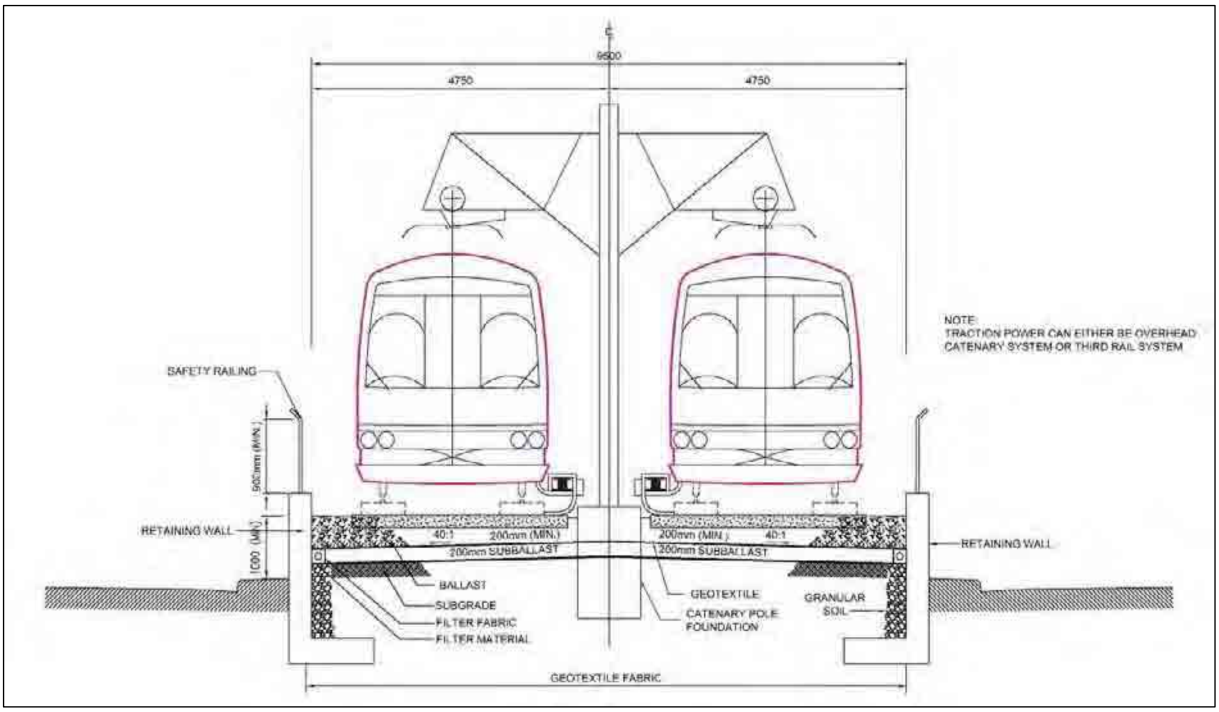
Source: HAIDEP Study Team

3) At-grade Guideway Sections

The sections of alignment between north tunnel portal (from Noi Bai International, the Nam Thanh Long portal) and the south tunnel portal near Thuong Dinh will be at grade. In order to avoid flooding of the track, the rail level will be located above flood levels along the route.

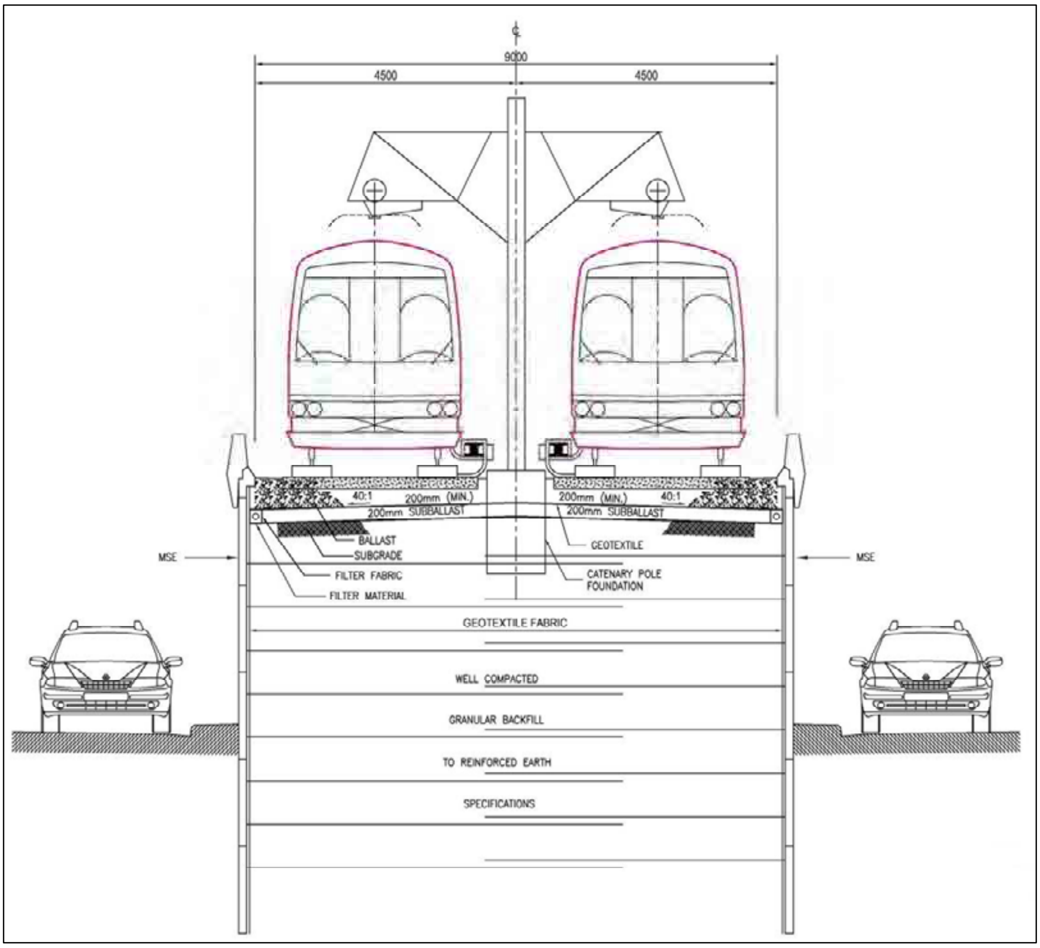
Depending on the final track alignment, the track will therefore be on an earth-retaining structure, details of which are as shown in the typical drawings.

Figure 4.1.3 Typical At-grade Section



Source: HAIDEP Study Team
Note: Traction power can either be overhead catenary system or third rail system

Figure 4.1.4 Section on MSDR Wall



Source: HAIDEP Study Team

4) Underground Guideway

Due to right-of-way constraints and environmental issues within the central district of Hanoi City within Ring Road 2.5 from Tu Liem to Thuong Dinh, this section of alignment of the guideway will be underground.

The transition structures from an at-grade track to the tunnel portals and potential ventilation shafts are located on the center line of the Highway at Ha Dong, Nam Thanh Long and at Noi Bai International airport.

It is expected that the transition structures, portal and ventilation structures will be constructed using cut and cover methods. The tunnels will be constructed by TBM.

The UMRT Line 2 comprises an Up Line and a Down Line. Therefore, there is the option of constructing one rail line per tunnel, i.e. two tunnels required, or one larger diameter tunnel containing both rail lines. Some issues to be taken into account in deciding which is the most appropriate option for UMRT Line 2, are presented in Table 4.1.1.

Table 4.1.1 Comparison of Twin TBM Tunnels versus a Single TBM Tunnel

Issue	Twin TBM Tunnel	Single Large Tunnel
Internal Diameter	5.4m	9.9m
Segment Lining Thickness	350mm	400mm
TBM Diameter	6.1m	10.7m
Excavated Tunnel Perimeter	19.16m x2 = 38.33m	33.62m
Excavated Tunnel Area	29.22sqm x 2 = 58.45sqm	89.92sqm
Tunnel Spacing	6.1m	NA
Minimum Clear Zone Underground / Wayleave (including 0.5m contingency either side)	19.3m if tunnels not stacked. 7.1m if tunnels stacked (but need adequate horizontal distance to rotate tunnels to and from stacked arrangement).	11.7m
Support	Perimeter similar to one large tunnel but lining thinner.	Perimeter similar to two smaller tunnels but lining thicker.
Ventilation	Each tunnel independent of other. Piston effect possible.	Less piston effect due to opposing train direction.
Cross-passages	Cross-passages required where spacing between station ends greater than 1000m. Each cross passage will require special treatment measures, using jet grouting or ground freezing.	Not Required
Internal Works	Minimal trackbed-may be single stage.	Deep ballast fill or pre-cast stage one trackbed.
Tunnel Incident / Emergency Evacuation	Each tunnel independent thus an incident in one tunnel need not adversely impact the other. But two walkways required.	Incident would impact both rail lines. But only one walkway required.
Turnouts, Crossover, Station Approaches	Can be partly accommodated by deviation from standard tunnel spacing.	Cannot be accommodated in tunnel.
Vertical and Horizontal Tunnel Alignment	Each tunnel independent thus within limits each can be separately deviated to accommodate local obstruction; requirements, etc.	Any tunnel deviation has similar impact on both rail line alignments.
Excavation Stability	Smaller tunnel diameter means less excavated face area; hence greater stability	Larger tunnel diameter means greater potential for different conditions across the excavated face
Minimum Tunnel Depth	Can be shallower than single large diameter tunnel	Deeper than twin tunnels.
Tunnel Advance Rate	Notional 67m per week for one tunnel	Notional 66m per week for one tunnel
Program	For a given fixed length of the alignment, either excavation will take twice as long or multiple TBMs required.	Both rail lines excavated simultaneously.
Redundancy and Flexibility	More TBM machines hence potentially greater redundancy and more flexibility.	Less redundancy as less number of TBM machines.

Source: HAIDEP Study Team

Other than the number and cost of the TBMs, tunnel ventilation and fire safety are of particular significance in the selection of either twin tunnels or one large-diameter tunnel.

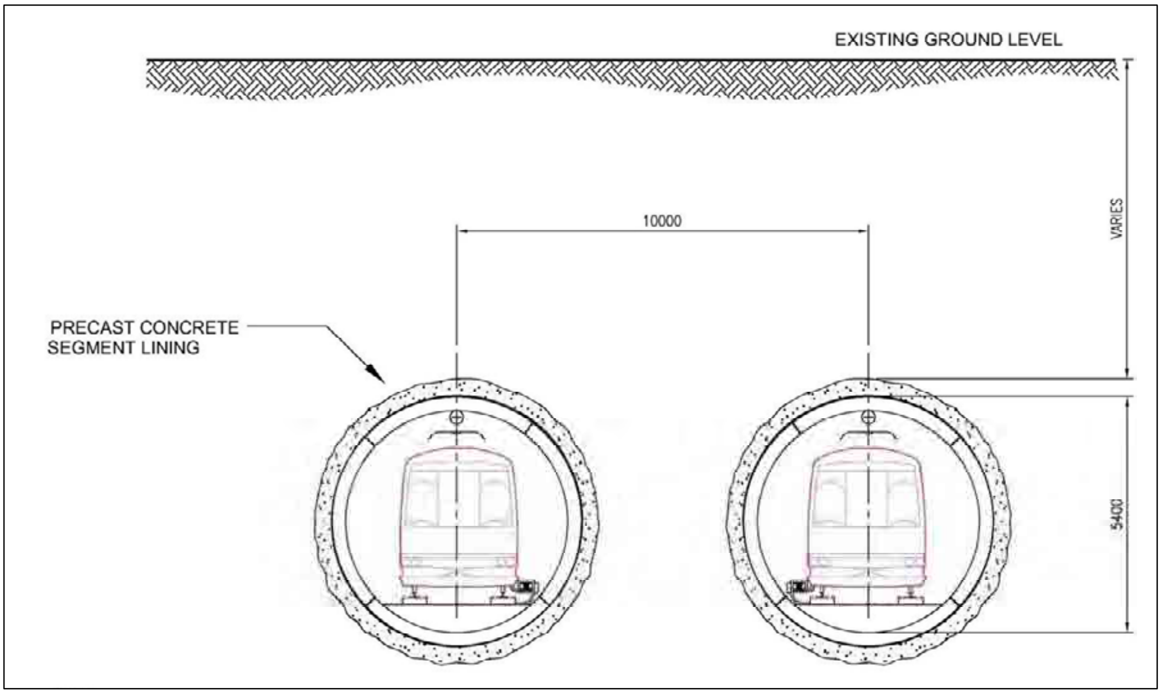
It will be a requirement that the tunnel ventilation will be designed and operated to assist safe evacuation from the tunnel in the event of a fire within the tunnel. Fresh air will be blown into the tunnel in a direction which forces the smoke flow to be at the opposite of the evacuation direction. The larger the tunnel diameter, the more air would be required to maintain the critical velocity. Hence, more costly, and larger capacity fans would be required.

For a 9.9m diameter tunnel, the capacity of the tunnel ventilation fans would be about 80 m^3/s to110m^3/s (based on max 3% gradient and fire load around 6.5 to 10MW). For twin tunnels, 40 to 60m^3/s tunnel ventilation fans are quite common.

In addition to the emergency situation, the normal cooling of the tunnel must also be considered. For twin tunnels, the piston effect would be more significant, as the blocking ratio is higher than in a larger twin-track tunnel. Therefore, the heat load generated by passengers and train auxiliaries could be effectively removed by the piston effect. For a large-diameter twin track tunnel, the piston effect is much reduced. Therefore, fans operating in push-pull mode or cooling/dumping could be required. The additional space for cooling/dumping AHU would have a cost penalty. Furthermore, a fan-assisted cooling scheme would mean that the fans would need to be operated continuously during the line operating period-a significant recurrent cost.

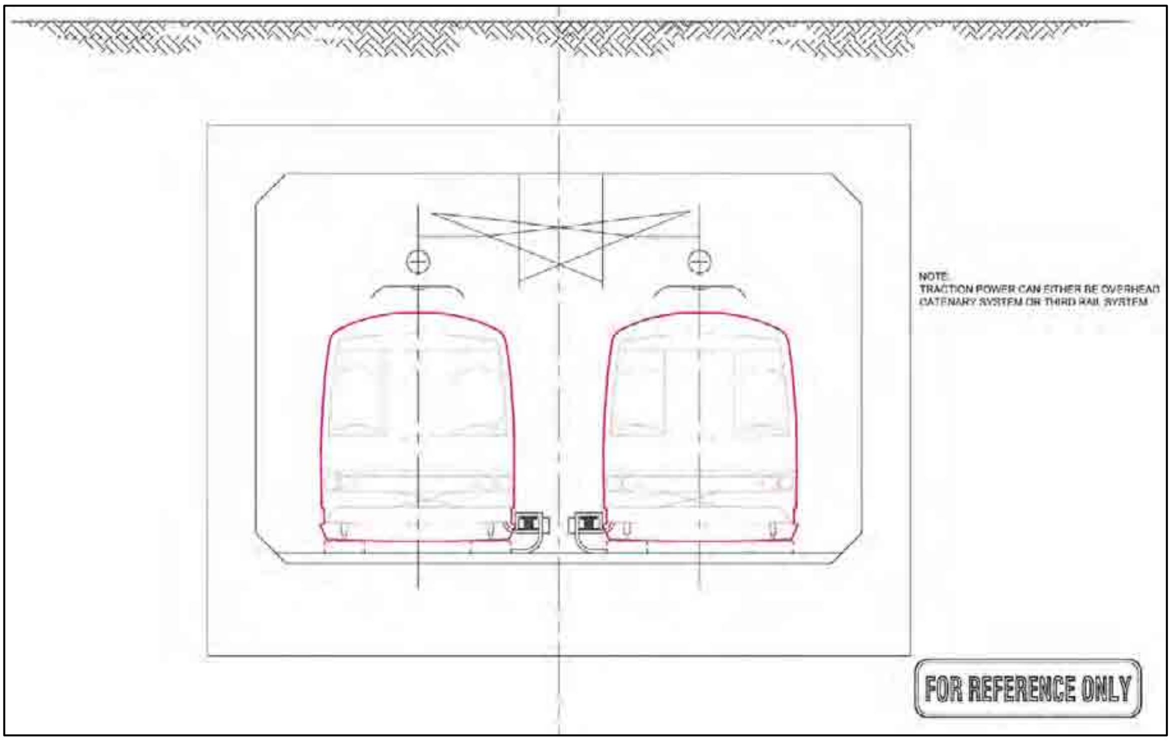
Taking account of all the above, at this time it is considered that twin tunnels are the best option for the bored tunnels of the UMRT Line 2. However, for the next stage, more detailed analysis should be undertaken to confirm the best option.

Figure 4.1.5 Typical Section of Bored Tunnel (Single Track)



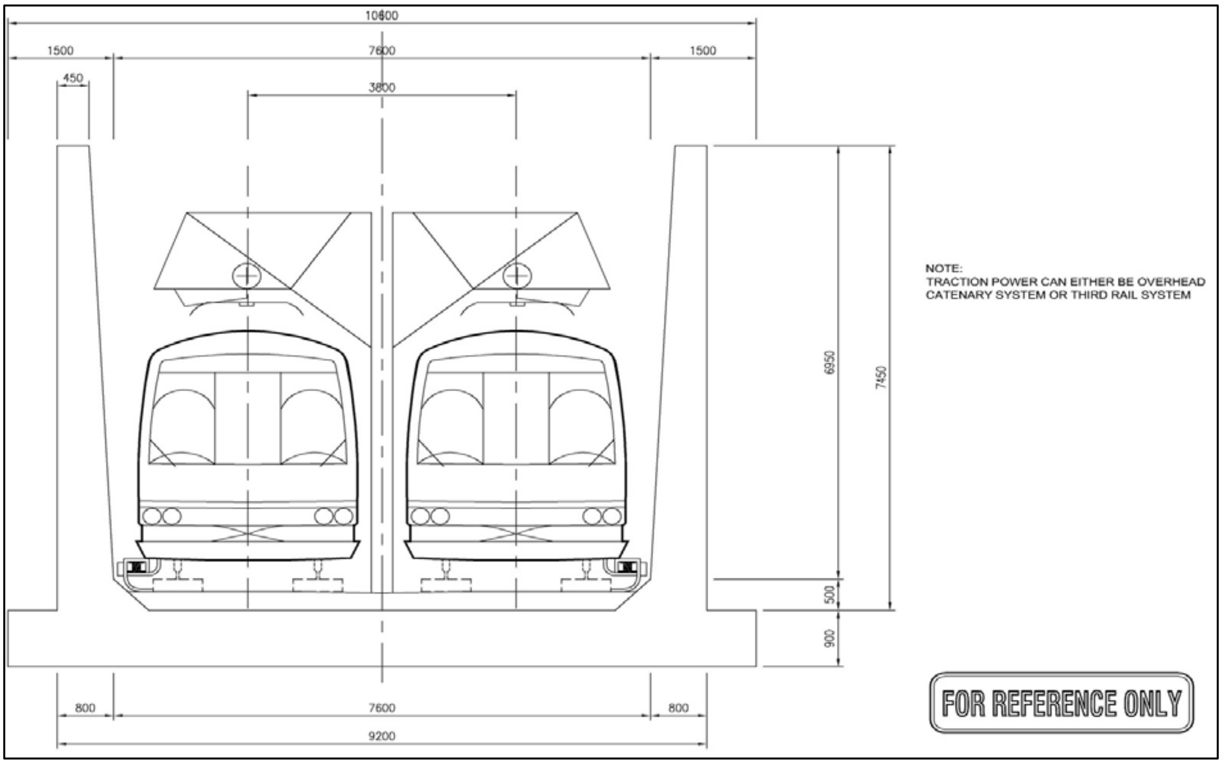
Source: HAIDEP Study Team

Figure 4.1.6 Typical Section of Cut & Cover at Tunnel Portal (Twin Track)



Source: HAIDEP Study Team

Figure 4.1.7 Typical Section of Cut & Cover at Tunnel Portal (Twin Tract)



Source: HAIDEP Study Team

5) Operations Facilities

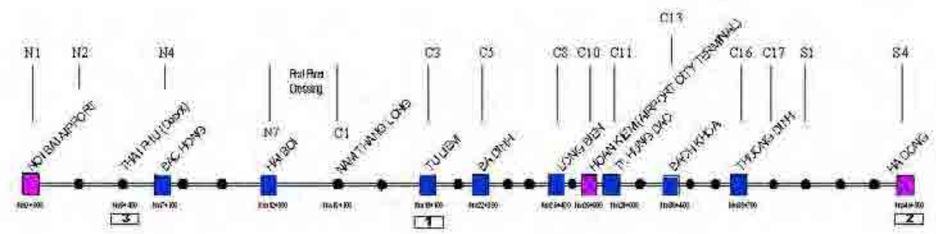
Necessary facilities to the operation of UMRT include:

(i) Terminal stations
(ii) Multimodal interchange
(iii) Intermediate stations
(iv) Airport station
(v) Cross-over
(vi) Turn-back track
(vii) Emergency siding/pocket track
(viii) Tunnel portal
(ix) Emergency services access
(x) Cross passage
(xi) Ventilation shaft
(xii) Tunnel drainage sumps
(xiii) Administration building
(xiv) Operations control center
(xv) Infeed substations
(xvi) Traction substation
(xvii)Flood gates

These facilities and their locations are outlined in Figure 4.18.

The tunnel ventilation system, power system, and the rail track system are further discussed in succeeding sections. Other systems are detailed elsewhere in the report.

Figure 4.1.8 Main Line Operations Facilities



Operations Facility	Key	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Terminal stations	TS	TS	TS				TS				TS	TS				TS	6
Multimodal interchange	MM	MM		MM		MM		MM	MM	MM	MM	MM	MM			MM	10
Intermediate Stations	INT	INT	INT		INT		INT	INT	INT INT	INT	INT	INT INT	INT INT	INT INT	INT INT		17
Airport Station	APT	APT				APT		APT			APT						4
Crossover (double turn out)	XT	XT	XT				XT	XT			XT		XT			XT	7
Turnback track	TBT	TBT														TBT	2
Emergency siding/pocket track	ES					ES		ES			ES		ES				4
Tunnel Portal	TP		TP			TP		TP					TP				4
Emergency Services access	ESA	ESA		ESA		ESA	ESA	ESA		ESA		ESA			ESA		8
Cross passage	CP	CP				CP				CP		CP					4
Ventilation shaft	VS	VS				VS	VS	VS	VS	VS	VS VS	VS	VS				10
Tunnel drainage sumps	DS	DS	DS			DS	DS	DS (2)	DS	DS	DS DS	DS	DS				11
Administration Building	ADB							ADB									1
Operations Control Centre	OCC							OCC									1
Depot & vehicle storage	D		D3					D1								D2	3
Infeed substation	ISS		ISS					ISS								ISS	3
Traction substation	TSS	TSS	TSS		TSS	TSS	TSS	TSS	TSS	TSS		TSS	TSS		TSS	TSS	12
Flood gate	FG	FG	FG			FG	FG	FG (2)		FG			FG				8

Source: HAIDEP Study Team

6) Tunnel Ventilation System

The Tunnel Ventilation System shall serve the main running tunnels and enclosed and/or underground station trackway, to cater for the following operating conditions:

(i) Normal operating conditions;
(ii) Congested or abnormal conditions; and
(iii) Emergency conditions.

Under normal operating conditions, scheduled trains are running freely through the system. Train movement normally shall provide sufficient air circulation through fresh-air inlets at stations and portals of tunnel sections. However mechanical ventilation may be required if natural ventilation induced by train piston effect is insufficient.

Under congested or abnormal conditions when trains come to rest in the running tunnels for any reason, including mechanical breakdown or operating difficulties, normal tunnel ventilation from the piston action of the trains will cease. Under such circumstances, sufficient forced-air flow shall be provided to maintain an appropriate quantity of fresh air, to meet physiological requirements, and to run the train-borne air-conditioning units and to ensure temperatures remain at safe levels within the cars.

In case of an emergency, the ventilation system in the tunnel shall ensure the following:

(i) The smoke and heat of a fire shall be kept away from people who might be trapped in a tunnel.
(ii) The direction of smoke movement shall be controlled, and a smoke-free path shall be provided for passengers' evacuation and for fire fighting operations.
(iii) Sufficient time shall be allowed for evacuation and emergency response.

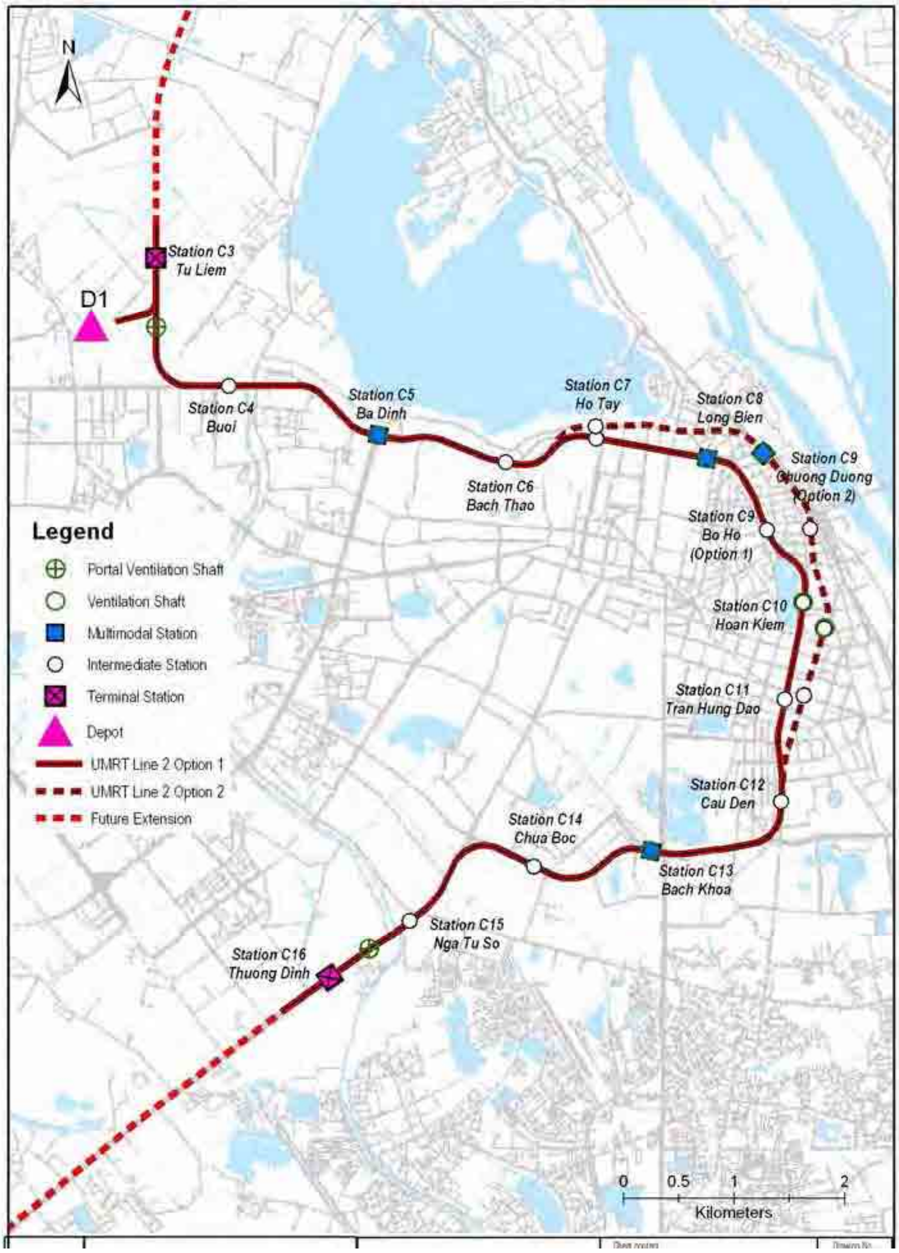
Large sections of UMRT Line 2 will be constructed underground therefore there will be a need for tunnel ventilation shafts along the underground section of the route. The spacing of the shafts will be defined when further work is carried out on the tunnel ventilation system but would normally be provided at about 1 to 1.5km centers depending on the station spacing along the alignment. These ventilation shafts will normally be located as part of the station construction and will include space for services and also stairs for emergency services to access the underground section of the route.

Where station spacings are greater that 1.5km, standalone ventilation/emergency stairs may be required. Where these are not possible it may be appropriate to locate emergency crossovers between adjacent tunnels or include emergency service walkways along the tunnel.

Design standards are included in NFPA 130; however, these standards should be reviewed further as to their applicability in Asian context and the accepted operating practice on other urban mass transit systems in Japan, Hong Kong and elsewhere in the region.

The location of emergency stairs at stations and shafts should be reviewed in some detail in the next stage of development of the UMRT Line 2 system when precise station locations have been determined.

Figure 4.1.9 Tunnel Ventilation System



Source: HAIDEP Study Team

7) Power System

Power supplies will be required for rail system-wide functions and the stations such as but not necessarily limited to:

(i) Rail Traction;

(ii) Signaling;

(iii) Tunnel Ventilation Systems;

(iv) Station Environmental Control Systems; and

(v) Maintenance Depot and Workshop.

It is assumed that all power distribution within the city is overhead and provided at 11KV. Accordingly, it is assumed one power supply source to the stations can be readily provided from the existing overhead infrastructure. It is also assumed that the power can be readily down-rated to 318V/415V/616V as necessary by the power supply authority. This will need to be confirmed with the supply authority.

It is proposed to provide power to the rail traction and other system wide systems from the regional power grid to avoid any potential voltage variations that might be incurred in the city grid should traction supply be taken from the latter. The proposal is to provide two main in-feed substations at each end of the UMRT Line 2 Initial System, namely at Tu Liem and Thuong Dinh Stations to ensure dual supply. It is assumed the in-feed supply would be at 110kV.

Visual inspection reveals that high voltage supplies are available near the vicinity of Tu Liem and Thuong Dinh Station. It is proposed to down-rate the high voltage supply to 22kV which shall be run through the rail tunnel alignment to provide power to Traction substations located within the stations as well as providing a second power supply to the stations in the event that power supply from the city grid is disrupted. It is assumed that the supply authority will provide the in-feed substation and associated infrastructure. It will be necessary to confirm this with the supply authority.

The main infeed power system from the local electrical power company will be supplied to the system at an infeed substation most probably at 33KV AC. A secure infeed location close to an existing power supply line is therefore necessary early in the initial system to allow for test running and commissioning of the mainline and depot sites.

As the UMRT Line 2 is developed, additional infeed substations will be required in the north and south western extensions of the route to give security of supply and minimize voltage drops in the transmission system.

Additional infeed substations will be required in the later stages of the project development which are likely to be located at Bac Hong in the north and Ha Dong in the southwest.

It is likely that the traction power system for the UMRT Line 2 rolling stock vehicles will be 1500vdc. Therefore the AC supply current will be stepped down and converted to DC current to provide traction power to the rolling stock vehicles along the UMRT Line 2 route.

In order to minimize voltage drop in the overhead conductor lines, it is normal to relocate traction substations every three to five kilometers along the route.

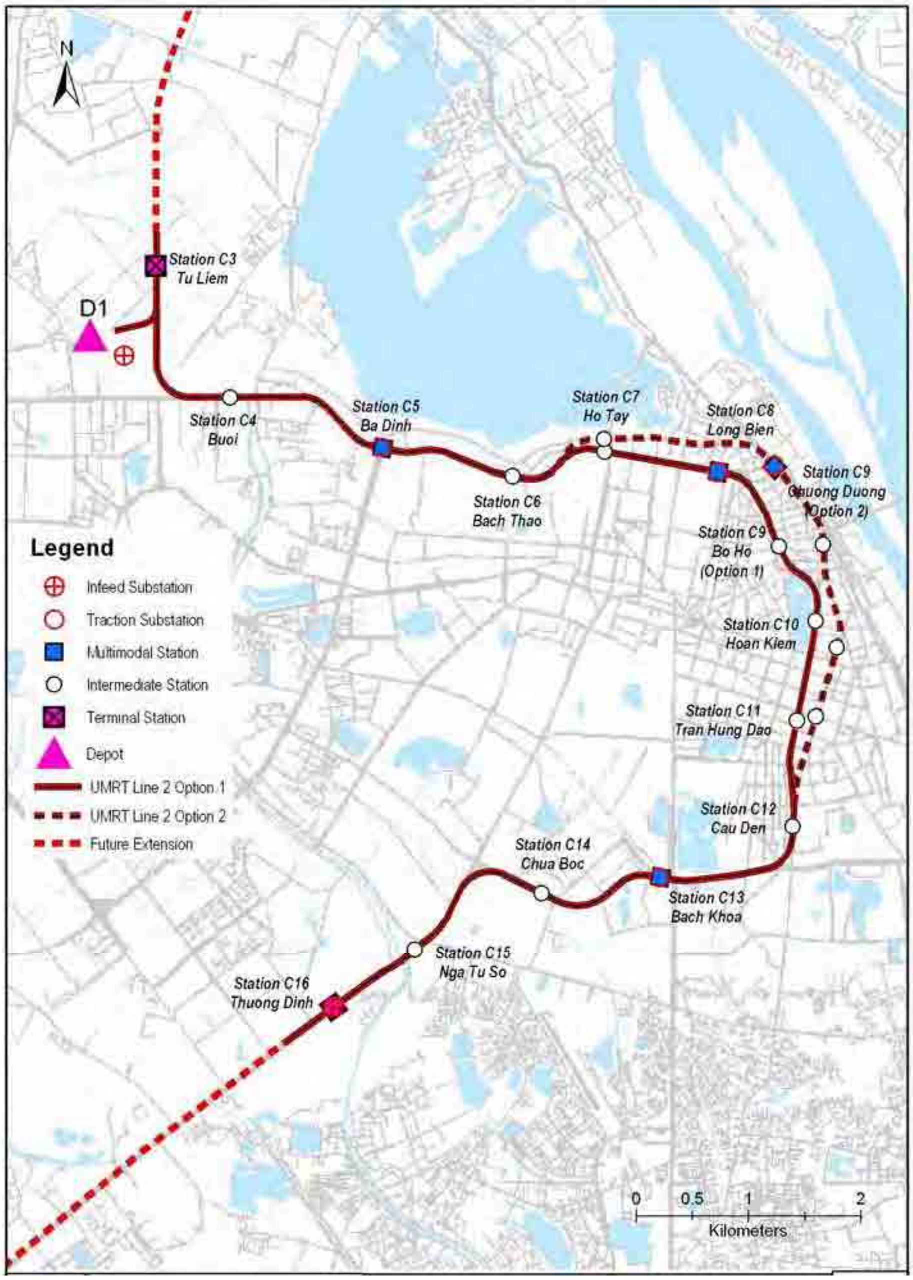
The following possible traction substation locations for the initial phase have been identified by the study team:

(i) Nam Thanh Long;
(ii) Tu Liem;
(iii) Ba Dinh;
(iv) Long Bien;
(v) Bach Khoa; and
(vi) Thuong Dinh.

In addition to the traction substations, there will be station substations required at each UMRT station. The size of equipment will be dependent on the station electrical and in particular air conditioning load which will be significantly higher at multimodal station sites.

If the main infeed substation is located at Tu Liem depot additional transformers will be required for the depot workshops and facilities.

Figure 4.1.10 Infeed Substation and Traction Power Substation Location



Source: HAIDEP Study Team

8) Rail Track System

In order to operate a close headway or high frequency urban mass transit system safely and efficiently, it is necessary to include a degree of operating flexibility in particular during emergency or degraded service operations to include track crossings and emergency sidings into the rail system design.

Standard gauge track is proposed for the UMRT rail system. The track support system will either be ballasted or tracked on the at-grade sections of the alignment and in the depot areas. For the track on the viaduct and in the tunnel sections, fixed track on concrete plinths would be a more appropriate track system. Rails would be designed to meet the actual rolling stock wheel loadings. Most modern Asian metro-type rail systems use a 60kg/m rail section. This should be reviewed during the next stage of the development of the UMRT Line 2 track specifications and standards.

Depending on the final phasing of the implementation of operations on the system, there will be a need to include track crossings at temporary and permanent terminal stations to allow trains to turnaround and operate on the other track.

Also in the event of a train breakdown, it will be necessary to remove the disabled train from the mainline and store the train on a non-revenue track. These emergency sidings should be located at regular intervals along the route so that the time to push a disabled train off the mainline track is short and the disruption to the revenue service is minimized.

In addition, in order to match the frequency or headway of rolling stock with passenger demand or to terminate some revenue services at intermediate points in the system and to maintain the headway on the mainline track, it will be necessary to construct three track platforms at some multimodal stations.

From the initial track operations plan, the following stations may have a three-platform configuration.

(i) Hai Boi;

(ii) Tu Liem;

(iii) Hoan Kiem Airport City Terminal; and

(iv) Thuong Dinh.

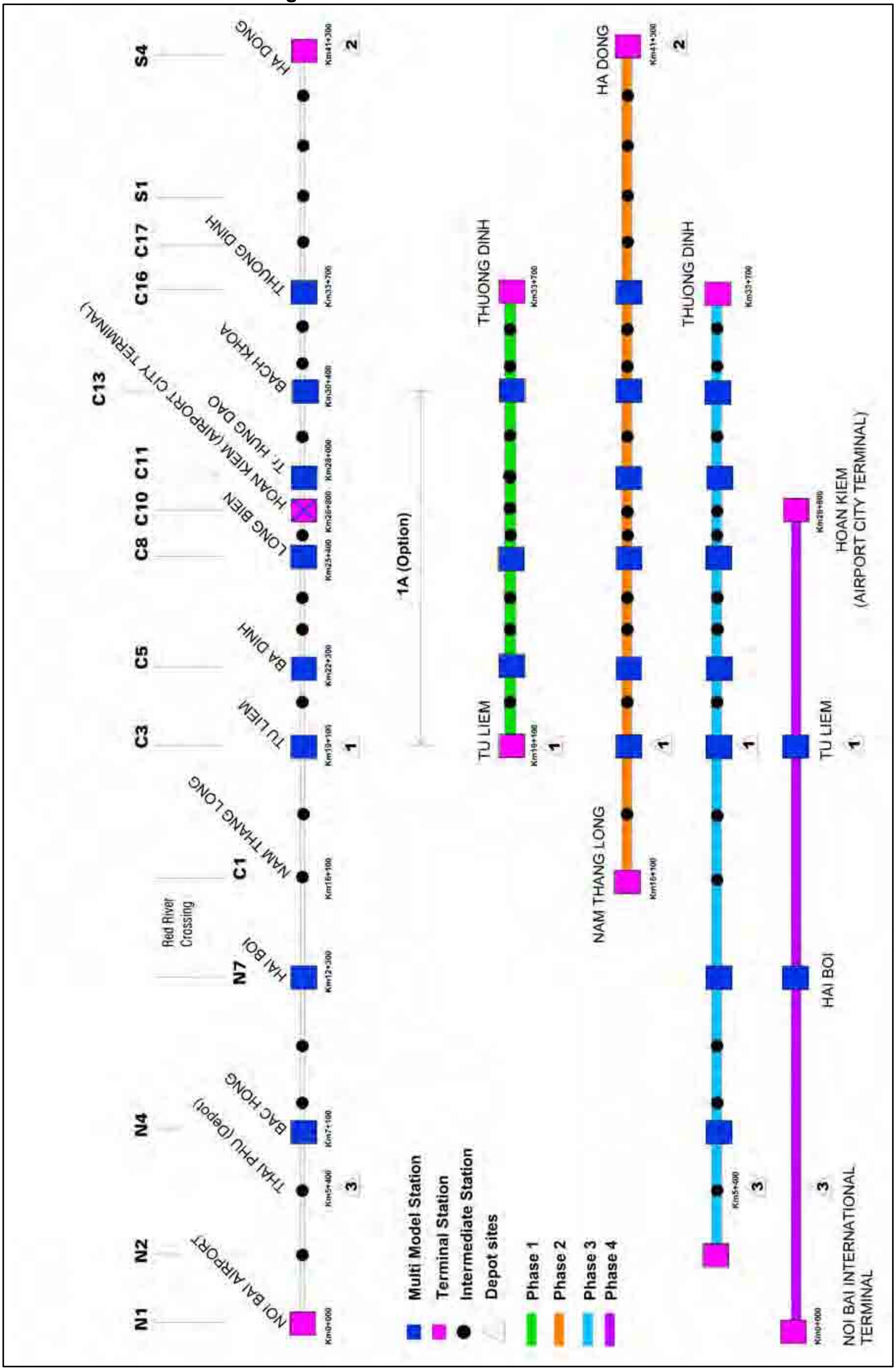
These platform sidings could be used in an emergency and can be used for stabling a crippled train set until it could be removed to the nearest depot for repair.

Additional emergency sidings may be located strategically along the route at the following approximate locations including Noi Bai International (kmO+O) and Ha Dong (km41+0).

The proposed track configuration showing crossovers and emergency sidings is shown on the operations rail schematic.

This schematic is based on the phased development of revenue service operations included in this study.

Figure 4.1.11 Rail Schematics Plan



Source: HAIDEP Study Team

4.2 Tunnel Construction

1) Tunnel Boring Machine

Tunnel boring machines are used to excavate circular cross-section tunnels through a variety of soil and rock types. TBM tunnel diameters can range from 1m (micro-TBMs) to almost 16m.

A TBM typically consists of one or two shields (large metal cylinders) and trailing support mechanisms. Located at the front end of the shield, a rotating cutting wheel excavates the tunnel in the soil or rock. The cutting wheel typically rotates at 4 to 10 rpm (depending on TBM diameter and geology). Behind the cutting wheel there is a chamber where the excavated material is transported away from the tunnel face. Depending on the type of TBM, the excavated material falls onto a conveyor belt system and is carried out of the tunnel, or is mixed with slurry and pumped back to the tunnel entrance.

Behind the chamber there is a set of hydraulic jacks supported by the finished part of the tunnel, which are used to push the TBM forward. The action here is caterpillar-like. The rear section of the TBM is braced against the tunnel walls or lining and is used to push the TBM head forward. At maximum extension, the TBM head is then braced against the tunnel walls and the TBM rear is dragged forward.

Behind the shield inside the finished part of the tunnel, there are several TBM support mechanisms, including excavated material removal; control rooms; rails for transport of the tunnel lining pre-cast segments, etc.

Very sophisticated TBMs are capable of excavating most types of ground including mixed tunnel face conditions, i.e. soil and rock together. When excavating in unstable water-bearing ground, these machines are able to stabilize the cut face by using foam and / or bentonite under pressure. Depending on the stabilization method used, such TBMs are referred to as either an Earth Pressure Balance (EPB) TBM or a Slurry TBM. An EPB TBM creates stability by maintaining pressure in the ground through which it is tunneling, with the aid of pressurized foam contained in the chamber. A Slurry TBM creates stability by pressurizing bentonite against the cut face. Where the functionality of both an EPB TBM and a Slurry TBM is combined into one TBM, this hybrid TBM is known as a MixShield TBM.

The advantages of excavating a long tunnel by using TBM include:

(i) The potential for extremely high average rates of advance from a single heading;
(ii) Reduced lengths for intermediate access adits and shafts;
(iii) Excavation of an exact tunnel profile, i.e. minimal overbreak;
(iv) Minimal impact on adjacent structures in terms of settlement of soils, hence safer excavation is achieved in urban areas;
(v) Reduced support requirements;
(vi) Mechanical excavation is less labor intensive and provides much safer working conditions;
(vii) Fewer access facilities, spoil disposal sites and routes are required;
(viii) 24-hour working in urban areas without noise restrictions.

For large diameter tunnels, the potential disadvantages of TBM excavation are considered to be:

(i) High plant costs where new TBMs are to be employed, requiring upfront financing in contracts;
(ii) Large lead-time for manufacture and delivery. This can be as high as 12 months;
(iii) Little flexibility on circular profile, curvature and enlargements;
(iv) Higher learning time required for familiarization;
(v) Performance risk when unexpected variations in geological conditions are encountered.

Geological risks are intensified for TBM excavation due to the higher plant costs involved and the higher advance rates achievable. Such risks, both real and imagined, can be mitigated by:

(i) Conducting high quality, comprehensive but targeted site investigations;
(ii) Using improved forms of contract including risk sharing;
(iii) Measurement contracts; and
(iv) Partnering.

In the context of UMRT Line 2, where a TBM is used to excavate a tunnel between stations, the programs for the tunnel drives will be dictated in part by the programs of the stations through which they pass. In order to maintain tunnel stability, construction of the station diaphragm walls should be completed ahead of the tunneling works. The critical activities at the beginning of the project will therefore be the installation of the station walls in the critical stations through which the TBMs will pass.

2) Geotechnical Implications on TBM Selection

Based on the results of the limited site investigation undertaken to date, it is apparent that the ground along the line of the UMRT Line 2 tunnels will comprise either clayey silts / silty clays, or sand, silty sand and gravels.

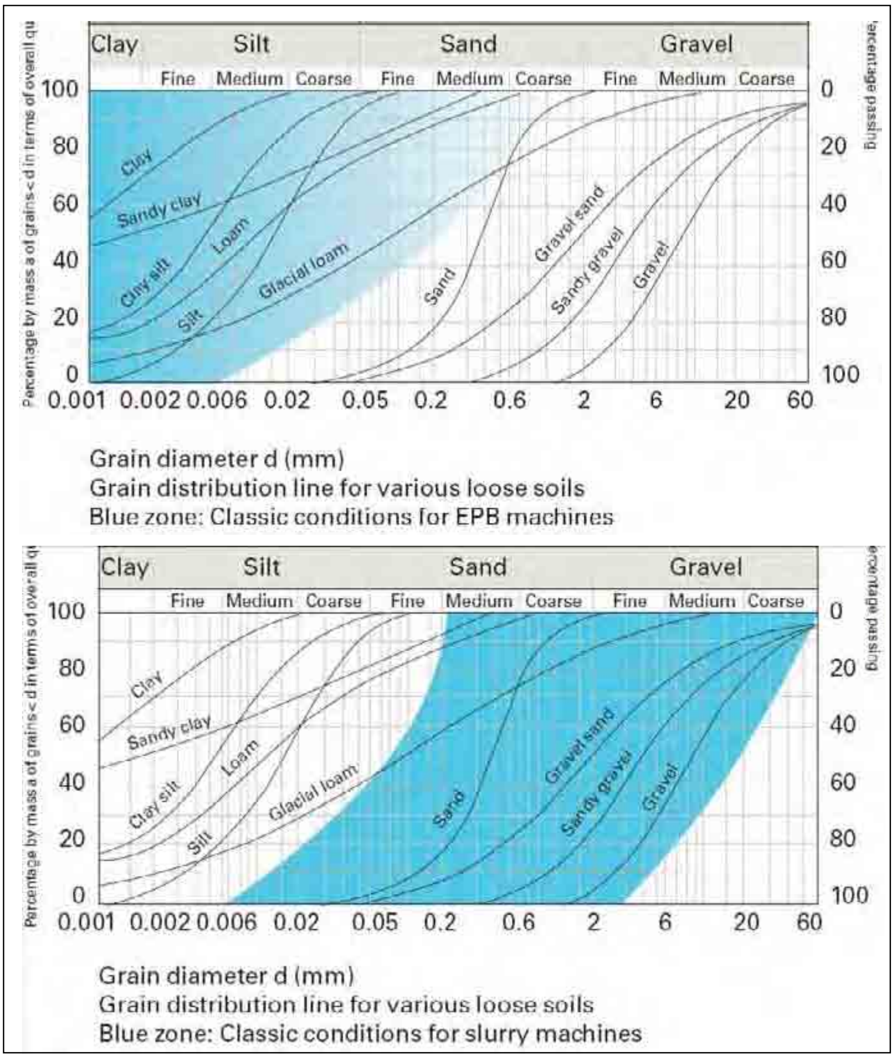
In loose sands and gravels conditions, a Slurry TBM has advantages. The pressurized slurry counteracts both the water and earth pressures. If the ground contains adequate clay content, water alone can be used. Otherwise a water-bentonite or water-polymer suspension is used to create a thin impermeable film or filter cake that seals the tunnel face. The supporting suspension is added to the upper section of the TBM excavation chamber and the ground/ suspension mixture extracted at the lower part where a stirring arrangement is used to prevent silting and ensure that a homogeneous medium is removed.

For an EPB TBM, clayey ground additives such as water, bentonite or chemical foams are applied to create an 'earth slurry' used to balance both water and earth pressures. The excavated material is normally excavated via a screw conveyor.

There are published relationships based on the Particle Size Distribution (PSD) of soil from which the suitability of tunnel excavation by either EPB TBM or Slurry TBM can be assessed. Examples of such relationships are shown in Figure 4.2.1.

Taking account of the above, the suitability of TBM type for the soils to be encountered along the line of the UMRT line 2 bored tunnels is indicated in Table 4.2.1.

Figure 4.2.1 Assessment of TBM Suitability Based on Particle Size Distribution



Source: Various publications

Table 4.2.1 Suitability of TBM Type for the UMRT Line 2 Bored Tunnels

Formation	Description	SPT	Slurry TBM	Earth Pressure Balance TBM
Thai Binh 3-4	Alluvial Clay, Clayey Silt	5 to 6	Probably Not Suitable	Suitable
Thai Binh 1-2	Loose to Medium Dense Alluvial Sand and Silty Sand	6 to 15	Suitable	Marginal. Soil Conditioning Probably Required
Vinh Phuc 3	Very Variable Alluvial Lacustrine Silty Clay	7 to 12	Not Suitable	Suitable
Vinh Phuc 2	Alluvial Clayey Silty Sand with some lenses of Dense to Medium Dense Gravel	15 to 30	Suitable	Marginal. Soil Conditioning Probably Required
Vinh Phuc 1	Alluvial and Prolluvial Dense to Very Dense Gravel and Cobbles with some Clayey Silt	30 to over 50	Suitable	Not Suitable

Source: HAIDEP Study Team

The soil type to be encountered in any particular length of the UMRT Line 2 bored tunnels will depend on the geographic location of the tunnel and the depth of tunnel of that location. The total potential length of bored tunnel associated with the ultimate extent of UMRT Line 2 south of the Red River, is about 15km. Currently, there is limited geotechnical drillhole data which is only for the 12km of the total length. Notwithstanding, based on a TBM tunnel diameter of 6.2m, the percentage of the different soil formations that would be entered at different average tunnel depths is summarized in Table 4.2.2.

Table 4.2.2 Tunnel Depth Versus TBM Suitability

Depth to Tunnel Roof (m)	Thai Binh 3-4	Vinh Phuc 3	Total	Thai Binh 1-2	Vinh Phuc 2	Vinh Phuc 1	Total	Thai Binh 3-4
	EPB	EPB	EPB	Slurry	Slurry	Slurry	Slurry	EPB
6.2	38%	31%	70%	23%	7%	0%	30%	6.2
12.4	13%	27%	40%	33%	25%	2%	60%	12.4
18.6	0%	0%	0%	25%	68%	7%	100%	18.6

Source: HAIDEP Study Team

From the above assessment, it is apparent that majority of material along the likely bored tunnel level is best suited to excavation by Slurry TBM. However, there will be interspersed zones best suited to an EPB TBM.

Consequently, subject to further detailed investigation in the next stage, it is currently considered that a Mix Shield TBM is the most suitable for excavating the UMRT Line 2 bored tunnels.

3) TBM Performance in Soils

Prediction of advance rates for TBMs in soil is largely a function of the ease of applying support measures and production in terms of the number of rings installed/shift. Various case histories are available to illustrate that sustainable average advance rates in long tunnels of 4m/day up to 25m/day can be achieved. Some typical actual performance for two different diameter Mix Shield TBMs are presented in Table 4.2.3. It is noted that for the examples given, the 12m diameter TBM achieved almost the same rate of progress as the 7.5m diameter machine.

Table 4.2.3 Typical Mix Shield TBM Advance Rate in Soil

TBM Activity		7.5m Dia Mix Shield	12m Dia Mix Shield
Delays for Segments	%	14	6
Cutter Intervention	%	42	37.2
Downtime for Spoil Disposal	%	12	12
TBM Maintenance / Probing	%	12	12
Survey / Water / Ventilation	%	6	6
TBM Effective Utilization	%	14	27.3
Advance Rate (120 working hours per week)	m per week	67.2	65.6
	m per year	3,494	3,411

Source: HAIDEP Study Team

The length of UMRT Line 2 alignment in tunnel south of the Red River is about 15km of which about 12km could be constructed by tunnel boring machine methods. Hence if there were twin tunnels, the total length of bored tunnel to be excavated would be 24km. On the basis of the advance rates given in Table 4.2.3 above, this would take about 51 months (4.25years) machine time to excavate, assuming either two 6.2m diameter TBMs or one 10.6m diameter TBM plus mobilization time of approximately nine months.

4.3 Red River-Crossing

1) Basic Criteria Relevant to Crossing

According to the Report on the Study on the Red River Inland Waterway Transport System in the Socialist Republic of Vietnam (January 2003), for the purposes of navigation, the section of the Red River that includes Thang Long Bridge and Long Bien Bridge is classified as Class II.

Clearance information for these existing bridges is given in Table 4.3.1.

Table 4.3.1 Vertical Clearance under Existing Red River Bridges

Bridge	Thang Long	Long Bien
Elevation of Girder Bottom	21mAHD	15.13mAHD
H5%Red River Water Level	9.7mAHD	9.52mAHD
Vertical Clearance under Bridge	11.3m	5.61m

Source: HAIDEP Study Team

Based on Class II, the navigational requirements determined by that Study for year 2010 and beyond and the implications thereof are as indicated in Table 4.3.2.

Table 4.3.2 Red River Navigation Channel Requirements at Proposed UMRT Line 2 Crossing

Aspect	Requirement
Least Available Depth (LAD) of Navigation Channel	2.5m
Lowest Low Water Level	2mAHD
Implied Required Maximum Elevation of Deepest Section of Red River Channel	0.5m
Least Available Width (LAW) of Navigation Channel	50m 2-lane channel 150m 4-lane channel (note the report recommends that a 4-lane channel should be adopted)
Vertical Clearance under a Bridge	Class II H5% + 9m (Note that because there are existing bridges in the same river section that have a clearance of 7m or less, the Study actually proposed H5% + 7m. However, for the purpose of the UMRT Line 2 Feasibility Study, it is considered the full Class II standard should be used).
Implied Structure Minimum Soffit Elevation of a UMRT Line 2 Bridge Crossing over the Red River	18.7mAHD
Design Vessel for this section of the Red River	600 DWT

Source: HAIDEP Study Team

2) Geology and Topography

At this time, there is only one borehole available near the location of the proposed UMRT Line 2 Red River crossing. Consequently, the full geological cross-section of the Red River at the location of the proposed UMRT Line 2 crossing is not known (e.g. Is there a buried channel? How mobile is the level of the base of the channel?). Furthermore, there is currently no data on the topography of the riverbed.

However, using the limited data available, a cross-section is conjectured (see Figure 4.3.1). Some relevant details from that cross-section are given in Table 4.3.3.

Table 4.3.3 Crossing Widths and Existing Ground Levels

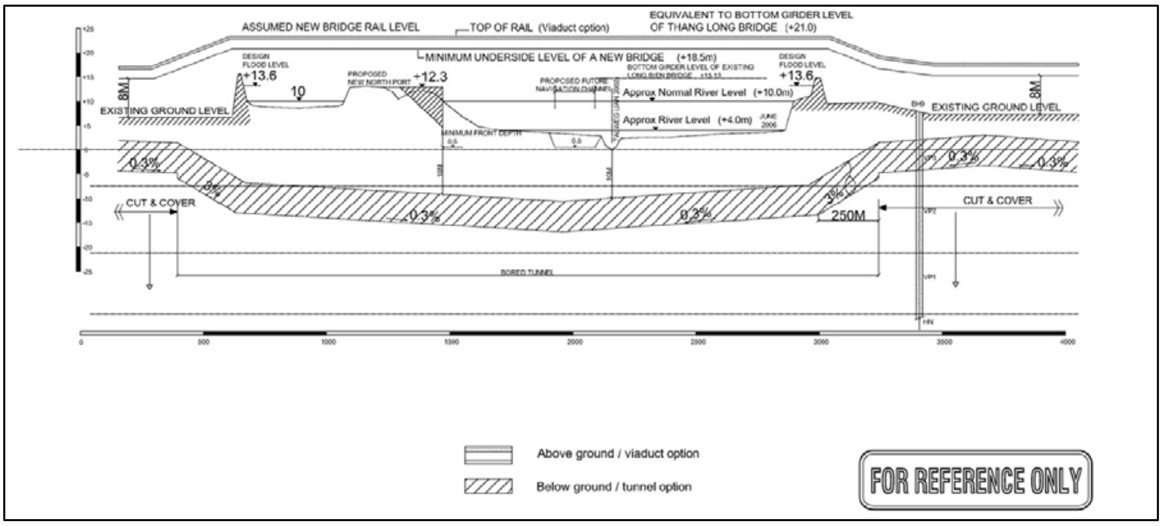
Cross-section	Requirement
Horizontal Distance between North and South Dykes.	2,420m
Horizontal Distance from Deepest Part of Red River Channel to North Dyke	1,320m
Horizontal Distance from Deepest Part of Red River Channel to South Dyke	930m
Assumed Ground Level, North of North Dyke	6.5mAHD
Assumed Ground Level, South of South Dyke	7.0mAHD

Source: HAIDEP Study Team

3) Crossing Implications

There are two options, i.e. tunnel or bridge crossing, as illustrated in Figure 4.3.1. The implications with respect to the length of the inclined approaches for a Red River crossing by either a tunnel or bridge are presented in Table 4.3.4 and Table 4.3.5, respectively.

Figure 4.3.1 Red River Cross-Section and Crossing Options



Source: HAIDEP Study Team

Table 4.3.4 Implications of a Bored Tunnel Red River Crossing

Cross-section	Requirement
Assumed Internal Diameter of Bored Tunnel	5.4m
Assumed Segment Lining Thickness	350mm
Assumed Bored Tunnel Excavated Dia	6.1m
Assumed Distance from Bored Tunnel Internal Crown to Top of Rail Level	4.5m
Assumed Cover to Top of Structure of a Land-side Cut and Cover Tunnel	3.5m
Assumed Top Slab Thickness of Cut and Cover Tunnel	750mm
Assumed Distance from Bottom of Top Slab of Cut and Cover Tunnel Structure to Top of Rail	4.6m
Implied Minimum Distance from Ground to Top of Rail in Cut and Cover Structure	8.8m
Implied North Landside Cut and Cover Tunnel Maximum Top of Rail Level	-2.3mAHD
Implied South Landside Cut and Cover Tunnel Maximum Top of Rail Level	-1.8mAHD
Assumed Maximum Rail Gradient in Approach to Bored Tunnel Crossing	3%
Assumed Maximum Horizon Distance to Maximum Rail	250m
Assumed Minimum Rail Gradient in Remainder of Bored Tunnel Crossing	0.3%
Presumed Minimum Clearance between the Deepest Section of the Red River Channel and the Bored Tunnel External Crown	10m
Assumed Maximum Elevation of Bored Tunnel Crown Extrados Beneath Deepest Part of Red River Channel	-9.5mAHD

Source: HAIDEP Study Team

Table 4.3.5 Implications of Initial Approach to Crossing Being on Elevated Viaduct

Cross-section	Requirement			
Minimum Underside Level of Bridge	18.7mAHD			
Assumed Distance Underside of Bridge Deck Top of Rail Level	2.5m			
Implied Minimum T pod Rail Level on Bridge	21.2mAHD			
Assumed "Level" Approach viaduct Height from Top of Rail to Ground Level	8m			
Implied "Level" Approach Viaduct Top of Rail Level	15.0mAHD			
Different in Level between "Level" Approach Viaducts and Bridge	6.2m			
Implied Horizontal Distance Approach Viaduct to Bridge at Gradient	1in	200	0.5 %	1,240m
	1in	100	1%	620m
	1in	50	2%	310m
	1in	33.3	3%	207m
Difference in Southside Level between "Level" Approach Viaducts and Top of Rail Level in Bored Tunnel				16.8m
Implied Horizontal Distance Approach Viaduct to Bored Tunnel at Gradient	1in	200	0.5%	3,360m
	1in	100	1%	1,680m
	1in	50	2%	840m
	1in	33.3	3%	560m

Source: HAIDEP Study Team

The prime conclusion of the above appraisal is that if the initial approach to the Red River is intended to be by elevated viaduct, then a bridge crossing of the Red River is implied if the elevated viaduct at standard height continues into the zone about 1.7km south of the South Dyke. It is however preliminarily recommended to utilize a bridge crossing, considering cost implications.

4) Particular Tunnel Crossing Issues

The prime issue affecting the selection of a tunnel crossing is that there is currently no information concerning the nature and mobility of the river bed. Thus, comprehensive ground investigation will be essential before a decision can be made on whether or not a tunnel crossing is appropriate and practical.

However, based on the information from drillhole BH9, it is apparent that the majority of the bored tunnel crossing would be in the Vinh Phuc 2 formation, comprising alluvial clayey silty sand with some lenses of dense to medium dense gravel. This formation is of high permeability and is part of the primary aquifer used in Hanoi as a source of potable water. Hence, water in the tunnel will be a significant issue-water pressures could be of the order 200 to 300kPa (2 to 3 bar). A TBM working in slurry mode is thus implied.

The bored tunnel crossing itself would be at least 2.5km long and the distance between the stations on either side of the bored tunnel crossing is about 3.5km. Consequently at least one cross-passage would be required beneath the Red River. Construction of this under river cross-passage will represent a considerable construction challenge.

Because of the potential for flooding, it is possible that floodgates could be required both in the north and south landside approaches to the bored tunnel under the Red River.

5) Particular Bridge Crossing Issues

The future main navigation channel implies a bridge span of about 150m, which is long for a railway bridge. Thus a standard viaduct is probably not viable. It is also not long enough to warrant a major bridge such as a cable-stayed bridge. Thus, potential bridge alternatives are currently considered to be:

(i) An arch bridge with the main piers at approx 250m apart: This would be a steel structure with a deck depth of say 1.5m or deep enough to match the adjacent approach viaducts,

(ii) An extrados bridge with main piers at 160m apart: This would have a similar appearance to a cable-stayed bridge but with a much shorter pylon. The deck would be about four to five meter deep with stubby pylons about 15m high.

(iii) If a segmental bridge with haunches was considered: The haunches would be about 10m to 12m deep, with mid span depths of five to six meter. However, given the site situation this is considered to be not practical.

To comply with the navigational clearance, the bridge piers would be to 16 to 17m high and would probably be five meter thick and of hollow section for part height to cut down on weight. The piers would be about 6m wide and streamlined for flow and to handle impact loads. Pilecaps would be set with a bottom level at the lowest water level and would probably be 10m wide and 15m long and 3m deep supported on deep piles.

The selection of an appropriate form for the approach viaducts is likely to be influenced by local technology preference. If steel is preferred to concrete then spans could be up to about 45m with a continuous 2m deep deck. If concrete is preferred then shorter, prefabricated spans are likely to be the best choice, say pre-cast beams with spans of 25m and a deck depth of about 2m. However, again because of the site situation, it could be more appropriate to adopt longer approach spans say 70m, with a 4m deep, box girder continuous deck.

Similar to the main span, the approach piers would be up to 16 to 17m high and probably about 2.5m thick. Again, hollow sections would be used for part height to cut down on weight. The piers would be streamlined and about six meter wide.

4.4 Station Design and Construction

1) Station Locations

Station locations have been determined for the preferred alignment: Option 1 and Option 2. These stations are identified below:

Table 4.4.1 Station Location Options

Option 1			Option 2		
Code	Number	Name	Code	Number	Name
TU	C3	Tu Liem (terminal)	TU	C3	Tu Liem (terminal)
BU	C4	Buoi (intermediate)	BU	C4	Buoi (intermediate)
BAD	C5	Ba Dinh (multimodal)	BAD	C5	Ba Dinh (multimodal)
BAT	C6	Bach Thao (intermediate)	BAT	C6	Bach Thao (intermediate)
HOT	C7	Ho Tay (intermediate)	HOT	C7	Ho Tay (intermediate)
LO	C8	Long Bien (multimodal)	LO	C8	Long Bien (multimodal)
BO	C9	Bo Ho (intermediate)	CHD	C9	Chuong Duong (intermediate)
HOK	C10	Hoan Kiem (Airport Terminal)	HOK	C10	Hoan Kiem (Airport Terminal)
HU	C11	Hung Dao (multimodal)	HU	C11	Hung Dao (multimodal)
CA	C12	Cau Den (Intermediate)	CA	C12	Cau Den (Intermediate)
BAK	C13	Bach Khoa (multimodal)	BAK	C13	Bach Khoa (multimodal)
CHU	C14	Chua Boc (intermediate)	CHU	C14	Chua Boc (intermediate)
NGA	C15	Nga Tu So (intermediate)	NGA	C15	Nga Tu So (intermediate)
THD	C16	Thuong Dinh (terminal)	THD	C16	Thuong Dinh (terminal)

Source: HAIDEP Study Team

2) Station Descriptions for Preferred Alignment Option 1

(1) Station Aesthetics

It is envisaged that the architectural treatment of the typical UMRT Line 2 stations will be contemporary in nature, recognizable from a distance by distinctive roof structures and entrances, which will contrast with the various building types and complement the appearance of the futuristic looking vehicle rolling stock on the UMRT Line 2 Transit System.

The multimodal multi-level station at Long Bien will interchange with the proposed UMRT Line 1 will require a different concept to the typical intermediate line stations, and will have a strong physical connection to the Ancient Quarter and the nearby Long Bien Bridge. For this reason the appearance of the station will be to some degree integrated into the architecture of the Ancient quarter and underground connections to the surrounding urban redevelopment sites.

(2) Platform Layout

During the concept stage of the UMRT Line 2 system consideration was given to both center and side platform configurations in the stations.

In order to minimize the structure footprint and viaduct construction costs, a side platform configuration was adopted for elevated stations; however, for the at-grade and underground stations, in order to minimize the impact on the width of the travel lanes on the public road a center platform configuration has been proposed.

With the exception of the multimodal Interchange stations with Lines 1, 3 (a&b), 4 and Vietnam Rail, generally the stations will have center or side platforms serving either the west or eastbound line.

At the multimodal stations, the platform will be on different levels to allow transfer of passengers from one rail system to the other. The station platforms will be connected to the concourse level either by a walkway, staircase, escalators and elevators, details of which will be as indicated in the station drawings.

The platform and staircase dimensions will be dependent on the type of rolling stock vehicle capacity and frequency will be sized to conform with the safety requirements of NFPA130, means of escape.

For safety and environmental reasons, the outline design of the station envisions the inclusion of platform screen doors (PSD) at the underground stations.

The selected bidder should ensure that their system is capable of operating in the future with platform screen doors at other UMRT Line 2 station platforms.

(3) Concourse

The basic design assumes that the concourse will be located either above or below the platform level and will be either underground, at-grade or elevated. The concourse area will be connected to access walkways to the station entrances.

In the multimodal interchange stations, the concourse may be part of a public area at-grade/underground and must include adequate pedestrian circulation spaces to the adjacent entrances/access points to the station.

(4) Station Entrances

The key to success of the UMRT Line 2 system will be through good passenger access to and from the various public transport multimodal interchange facilities and potential commercial development sites adjacent to the respective UMRT Line 2 stations.

Entrances to the UMRT Line 2 stations from these facilities must be closely coordinated and integrated into the final UMRT Line 2 station design.

(i) Segregated walkways including underground crossings and elevated footbridges along the transport corridor;

(ii) Direct access to major multimodal transport interchanges including the World Bank priority bus service the multimodal stations, which in the initial system will include Tu Liem, Ba Dinh, Long Bien, Bach Khoa

(iii) Planned connections to the major residential, commercial developments at the UMRT Line 2 station sites;

(iv) Direct access to private car and motorcycle “park and ride” areas where motorists/cyclists can directly access the UMRT Line 2 system from the parking areas;

(v) Passenger road based feeder routes from other areas within Metro Manila must be provided including easy access to the UMRT Line 2 stations;

(vi) Provisions for any other transit systems planned by the Government of the Vietnam including interchange with an underground transit systems at Tran Hung Dao; and

(vii) Road and access for private transport "drop off and pick up" points should be part of the entrance design of the stations which should include facilities for service/emergency vehicles at each UMRT Line 2 station site.

All UMRT Line 2 stations will have a bridge or underpass connection to both sides of the roadway, accessible 24 hours 7 days a week from grade level by elevator, escalator as well as staircases. Entrance structures should comply with the requirements of NFPA130 for means of escape from the respective stations.

For underground stations an adequate local flood protection measures including flood gates should be provided at each entrance to ensure no ingress of water into the station and tunnel areas.

Figure 4.4.1 Architectural Concepts

Source: HAIDEP Study Team

3) Station Descriptions for Preferred Alignment Option 1

(1) Tu Liem Station (Station C3)

This station is located at the north end of UMRT Line 2 Initial System along the northern extension of Nguyen Van Huyen Road and adjacent an approved and proposed development.

Location of stations north of this point for the UMRT Line 2 Initial System indicate relatively small patronage demands and therefore would not be cost effective in terms of capital expenditure per revenue unit or passenger kilometer metrics.

The station location is also well located to easily connect to the proposed main depot and workshop which will serve both the UMRT Line 2 Initial System and the Completed System.

This station will initially be a terminal station for the UMRT Line 2 Initial System and ultimately a multimodal "through" station with depot turnback facility when the UMRT Line 2 system is complete.

The proposed site for the station is a "greenfield" rural site, currently used for informal farming purposes, and therefore represents no known physical, social or environmental constraints.

In view of the latter it is proposed this station and approaching trackways would be constructed using cut and cover methodology. The station will be a two level structure with the platforms and trackways below ground and the concourse at ground level accommodating paid and unpaid areas. Such construction methodology would be more cost effective than a deep level underground station.

It is further proposed to integrate a shallow road underpass with the station construction to alleviate any potential for vehicular/pedestrian traffic conflict at surface level immediately adjacent the station. In this manner the station is able to provide an effective and sympathetic interface with the proposed development and its local environment with the station concourse providing an uninterrupted pedestrianized connection at ground level between communities either side of the proposed roadway.

By providing a partially underground station also allows for easy access of the trackway to ground level to suit the depot.

The station will consist of one island platform and one side platform to accommodate the running tracks and a pocket track with associated turnouts. In addition, the station also provides a turnback facility leading to the adjacent depot site.

While the form of construction of the UMRT Line 2 north of this station will be subject to further study, the partial underground station at Tu Liem can easily accommodate an elevated, at grade or cut and cover construction method for the northerly extension.

(2) Buoi Station (Station C4)

This station shall be located underground under Hoang Quoc Viet Street near the junction with Duong Buoi Road. The station would be located immediately west of the canal which runs along Duong Buoi Road.

By locating the station within the road reserve of Hoang Quoc Viet Street, it will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box.

This station will be a two level intermediate station consisting of an island platform and a concourse level incorporating paid and unpaid areas above.

In order to accommodate the proposed alignment, it will be necessary for UMRT Line 2 to be constructed using bored tunnel methodology in order to pass under existing buildings on the Up-side and Down-side of the station as well as minimize the extent of surface disruption that would be required using other construction techniques (such as cut and cover). In addition, it will be necessary to pass under the canal to the east of the station. Therefore the station construction will be relatively deep. It is proposed that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

To accommodate bored tunnel techniques for the trackway, it is proposed to locate a portal structure interfacing the bored tunnel and the cut and cover trackway between Buoi and Tu Liem Stations.

(3) Ba Dinh Station (Station C5)

The station will be a multimodal underground station along Hoang Tham Street at the junction of Hoang Tham and Lieu Giai Van Cao Roads with the approaching running rails located in twin bored tunnels.

The station location will be within the secondary dyke to Ho Tay Lake along which Hoang Tham Road is located.

By locating the station within the road reserve of Hoang Tham Road will minimize the potential impact on land acquisition and any resettlement, disruption, building reconstruction, environmental impact, etc. since the road reserve is considered to be sufficiently wide to accommodate construction of the station box using cut and cover/top down construction techniques.

This station will also have to interface with the proposed UMRT Line 3 underground system which has a terminal station at this location. This interface has not been considered in this study and will require further study. This may require a fully integrated station development with interchange platforms and/or stacked stations/platforms depending on operating conditions, management, system interfaces, etc.

For the purposes of this study, the station has been designed as a two level station with an island platform and a concourse level incorporating paid and unpaid areas above.

(4) Bach Thao (Station C6)

This station will be an intermediate two level underground station with an island platform and concourse (paid and unpaid areas) levels.

This station shall be located under Hoang Hoa Tham Road near the junction with Giang Van Minh immediately west of the Botanical Gardens.

Since Hoang Hoa Tham Road is located along the secondary dyke to Ho Tay Lake, the station will be constructed within the dyke.

By locating the station within the road reserve of Hoang Hoa Tham Road will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box. The extent to which any trees, etc require removal has not been assessed.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology which will minimize if not avoid any potential disruption or damage to the surface environment.

The tunnels will need to be at sufficient depth to pass under the Botanical Gardens and associated lakes. Therefore the station construction will also be relatively deep.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(5) Ho Tay Station (Station C7)

This station will be an intermediate two level station with an island platform and concourse (paid and unpaid areas) level.

This station shall be located underground under Hoang Hoa Tham Road at the junction with Hung Vuong Road.

By locating the station within the road reserve will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimizing or avoiding any potential disruption or damage to surface infrastructure.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(6) Long Bien Station (Station C8)

This station will be a multimodal station which will interface with the nearby bus terminal and future alignment of UMRT Line 1 (Vietnam Rail).

This station shall be located underground between Phan Dinh Phung and Quan Thanh Roads and shall be a three level station with an island platform, an intermediate level (to assist with passenger circulation and accommodation of building services and necessary rail services) and a concourse level incorporating paid and unpaid areas.

It is anticipated that it will be necessary to carry out demolition of adjacent structures and buildings to accommodate construction of the station. Such demolition may incur land compensation and resettlement issues.

It will also be necessary to ensure the station location does not compromise or impact upon the above ground/elevated, heritage water tower and associated infrastructure immediately north of the proposed station location.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimizing or avoiding any potential disruption or damage to surface infrastructure. However, in view of the narrow streets and high density of buildings in this area there is a greater risk of potential damage to buildings and surface infrastructure.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(7) Bo Ho Station (Station C9)

This station will be a two level underground intermediate station located within the Ancient Quarter. The station will consist of an island platform and concourse incorporating paid and unpaid areas.

This station shall be located under Hang Ngang and Hang Dao Streets at the junction with Hang Bo and Hang Boc Streets.

In order to construct the station which is anticipated to be constructed using cut and cover/top down construction techniques, it will be necessary to resume and demolish buildings and surface infrastructure adjacent the proposed station because of the narrow streets. In addition, building demolition beyond the locality of the station may also be required to accommodate the potential for significant surface construction equipment that will be necessary for construction of the rail tunnels and station.

The location of the station, therefore, will require demolition of buildings of potential heritage value although such demolition does provide an opportunity for urban renewal. However, the benefits and potential impacts of these outcomes require detailed study and assessment.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology. It is anticipated that significant land compensation may be required.

(8) Hoan Kiem Station (Station C10)

This station will be a multimodal and terminal station for the future airport express connection. The station will be a two level station consisting of three side platforms for the running tracks and a pocket track with associated turnouts for the airport terminal and/or emergency.

This station shall be located underground below Dinh Tien Hoang Street immediately adjacent the east bank of Hoan Kiem Lake.

In order to construct the station which is anticipated to be constructed using cut and cover/top down construction techniques, it will be necessary to remove numerous trees of potential historic significance as well as destroy a number of potentially sensitive fauna and flora. Construction of the station box could also impact on immediately adjacent buildings and surface infrastructure because of the increased width of the station to accommodate the pocket track and associated turnouts.

It is also possible that construction of the underground tunnels and station could impact on the Hoan Kiem Lake because of the distance of the proposed rail alignment to the latter.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology.

(9) Hung Dao Station (Station C11)

This station will be a multimodal station and interchange with the UMRT Line 3. For purposes of this study this station design has not considered an integral design with the UMRT Line 3 station (this may be considered with on-going design development). The station has been designed as a two level underground structure with an island platform and concourse (paid and unpaid areas) levels.

This station shall be located under Hang Bai Street at the junction with Tran Hung Dao Street.

By locating the station within the road reserve, it will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box. It may be necessary to remove a number of trees in the immediate vicinity to accommodate construction of the station.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimizing or avoiding any potential disruption or damage to surface infrastructure.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(10) Cau Den Station (Station C12)

This station will be an intermediate two level underground station with an island platform and concourse (paid and unpaid areas) level. It is anticipated that the station box can be constructed using cut and cover/top down construction techniques.

This station shall be located underground under Pho Hue near the junction with Doan Tran Nghiep Road.

Locating the station within the road reserve will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box. However, it may be necessary to remove a number of trees to accommodate construction of the station box.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology therefore minimizing or avoiding any potential disruption or damage to surface infrastructure.

(11) Bach Khoa Station (Station C13)

This station will be an underground multimodal station and interchange with the UMRT Line 1 (Vietnam Railways).

For purposes of this study the station design has not considered an integral design with the UMRT Line 1 (this may be considered with on-going design development).

The station has been designed as a three level underground structure with an island platform level, intermediate level (to assist with passenger circulation and provision of building services and rail systems) and concourse level (paid and unpaid areas).

This station has been located under Duong La Thanh Road immediately west of UMRT Line 1 which is aligned along Duong Le Duan Street.

During the course of this study it became known that this road intersection is to be modified with the construction of Duong La Thanh/Dai Co Viet roads as an underpass below UMRT Line 1. It has not been possible to determine the details of the proposed underpass construction. Nevertheless, the proposed location of the station assumes that it is sufficiently westward to avoid conflict with the proposed underpass.

Further study of the underpass and its potential impact on the railway and station location shall be necessary recognizing that the high rise buildings immediately south of this location and the new existing water treatment plants along the down alignment may impose further constraints to the proposed alignment and station location.

In addition, the underpass will require the rail tunnels and station structure to be deeper than typically designed.

As an alternative it may be preferable to locate the station under Dai Co Viet Street immediately south of the Bay Mau Lake and east of the proposed road underpass. However, this would be subject to further study.

Notwithstanding the above, by locating the station within the road reserve will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box. It may be necessary to remove some trees in the immediate vicinity to accommodate construction of the station.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimizing or avoiding any potential disruption or damage to surface infrastructure. However, as noted above the vicinity of existing high rise buildings and the water treatment plant will require consideration.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(12) Chua Boc Station (Station C14)

This station will be an intermediate two level underground station with an island platform and concourse (paid and unpaid areas) level. It is anticipated that the station box can be constructed using cut and cover/top down construction techniques.

This station shall be located underground under Chua Boc Road near the junction with Tan That Tung Road.

It is anticipated that because of the narrow road reserve it will be necessary to acquire and demolish some of the buildings in the immediate vicinity of the station to accommodate construction of the station box. It will also be necessary to remove a number of trees to accommodate construction of the station box.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology therefore minimizing or avoiding any potential disruption or damage to surface infrastructure. However, land compensation issues may be necessary to accommodate the proposed alignment.

(13) Nga Tu So Station (Station C15)

This station will be an intermediate two level underground station with an island platform and concourse (paid and unpaid areas) level. It is anticipated that the station box can be constructed using cut and cover/top down construction techniques.

This station shall be located underground under Tay San Road immediately north of the junction with Truong Chinh Street.

The station has been located sufficiently northward to minimize any potential impact with the Tay Son Road overpass at Truong Chinh Street.

The station and railway tunnels will also be required to be deeper than the typical in order to pass under the canal immediately south of the road overpass.

A site inspection also revealed construction of a culvert/underpass structure at the north-east corner of the road overpass which will also necessitate a deeper construction than that typically designed. Construction details were not available at time of preparation of this report.

Notwithstanding the above, by locating the station within the road reserve will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology therefore minimizing or avoiding any potential disruption or damage to surface infrastructure.

It is anticipated that the rail alignment south of the station will rise to accommodate construction using cut and cover methodology for the railway or provide for the rail at grade or on an elevated structure, all providing more cost effective construction relative to bored tunnel. This will require a portal structure at the interface of the bored tunnels and the cut and cover sections south of the station and the adjacent canal.

(14) Thuong Dinh Station (Station C16)

This station is located at the south end of UMRT Line 2 Initial System along Nguyen Trai Street. It is proposed that the station is an underground two level structure with a single island platform and a single side platform to accommodate a pocket track with associated turnouts.

Location of stations south of this point for the UMRT Line 2 Initial System indicate relatively small patronage demands and therefore would not be cost effective in terms of capital expenditure per revenue unit or passenger kilometer metrics.

This station will initially be a terminal station for the UMRT Line 2 Initial System and ultimately a multimodal “through” station when the UMRT Line 2 system is complete.

The road reserve within which the station is located is sufficiently wide to accommodate the station structure and therefore minimize any potential impact on land compensation and resettlement or any environmental issues.

In view of the above it is proposed this station and approaching trackways would be constructed using cut and cover methodology. The station platforms and trackways will be below ground and the concourse at ground level accommodating paid and unpaid areas. Such construction methodology would be more cost effective than a deep level underground station.

It is further proposed to integrate a shallow road underpass within the station construction to accommodate traffic on Nguyen Trai Road and to alleviate any potential for vehicular/pedestrian traffic conflict at surface level immediately adjacent the station. In this manner the station is able to provide an effective and sympathetic interface with the proposed surrounding local environment, with the station concourse providing an uninterrupted pedestrianized connection at ground level between communities either side of the existing roadway.

While the form of construction of the UMRT Line 2 north of this station will be subject to further study, the partial underground station at Tu Liem can easily accommodate an elevated, at grade or cut and cover construction method for the northerly extension.

4) Station Descriptions for Preferred Alignment Option 2

The station locations and configurations for the preferred alignment Option 2 are the same as the preferred alignment Option 1 for the following sections:

(i) Tu Liem to Bach Thao Station, and

(ii) Cau Den to Thuong Dinh Station.

For this reason only the stations between Bach Thao and Cau Stations are discussed further for preferred alignment Option 2 since it is only those stations between the latter stations that vary in location.

(1) Ho Tay Station (Station C7)

This station will be an intermediate two level station with an island platform and concourse (paid and unpaid areas) level.

This station shall be located underground under Quan Thanh Road near the junction with Hung Vuong Road. This will require the station to be constructed within the secondary dyke to Ho Tay Lake

By locating the station within the road reserve, it will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimize or avoid any potential disruption or damage to surface infrastructure.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(2) Long Bien Station (Station C8)

This station will be a multimodal station which will interface with the existing bus terminal and the UMRT Line 1 (Vietnam Rail).

This station shall be located underground under Tran Nhat Duat at the junction with the Long Bien Bridge. The station will be a three level station with an island platform, an intermediate level (to assist with passenger circulation and accommodation of building services and necessary rail services) and a concourse level incorporating paid and unpaid areas.

It is considered that the station location will minimize and possibly avoid demolition of adjacent structures and buildings to accommodate construction of the station and therefore minimize/avoid any land compensation and resettlement issues. The station location also offers an opportunity to renew the existing bus terminal and interchange with minimal impact to existing infrastructure.

The station location is located within the primary dyke to the Hong River.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimize or avoid any potential disruption or damage to surface infrastructure. However, consideration will need to be taken in terms of the stability and integrity of the primary dyke to the Hong River.

It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

(3) Chuong Duong Station (Station C9)

This station will be a two level underground intermediate station located under Nguyen Huu Huan Road immediately south of Tran Nhat Duat Road. The station will consist of an island platform and concourse incorporating paid and unpaid areas.

It is considered that the road reserve is wide enough to construct the station using cut and cover/top down construction techniques while minimizing the necessity for demolition of buildings and surface infrastructure. It will, however, be necessary to remove a number of trees. However, because of the nature and location of Nguyen Huu Huan Road the potential environmental impact is considered minimal.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology. It is anticipated that because of the proposed alignment and station location there will be minimal or no land compensation issues.

(4) Hoan Kiem Station (Station C10)

This station will be a multimodal and terminal station for the future airport express connection. The station will be a two level station consisting of three side platforms for the running tracks and a pocket track with associated turnouts for the airport terminal and/or emergency.

This station shall be located underground below Ly Thai To at the intersection with Ngo Quyen and Nguyen Huu Huan Roads immediately adjacent the People' Committee Building and the "old" Ministry of Finance building.

The road reserve is considered sufficiently wide in this location to accommodate the construction of this station which will be wider than other typical stations. Station construction is anticipated to be constructed using cut and cover/top down construction techniques. It is considered there will also be minimal requirement for removal of trees and surface infrastructure.

While the station location could have direct access to Hoan Kiem Lake and surrounding buildings construction of the station and underground tunnels will have minimal or no impact on Hoan Kiem Lake and its surrounding parkland in the immediate vicinity of this alignment.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology.

(5) Hung Dao Station (Station C11)

This station will be a multimodal station and interchange with the UMRT Line 3. For purposes of this study this station design has not considered an integral design with the UMRT Line 3 station (this may be considered with on-going design development). The station has been designed as a two level underground structure with an island platform and concourse (paid and unpaid areas) levels.

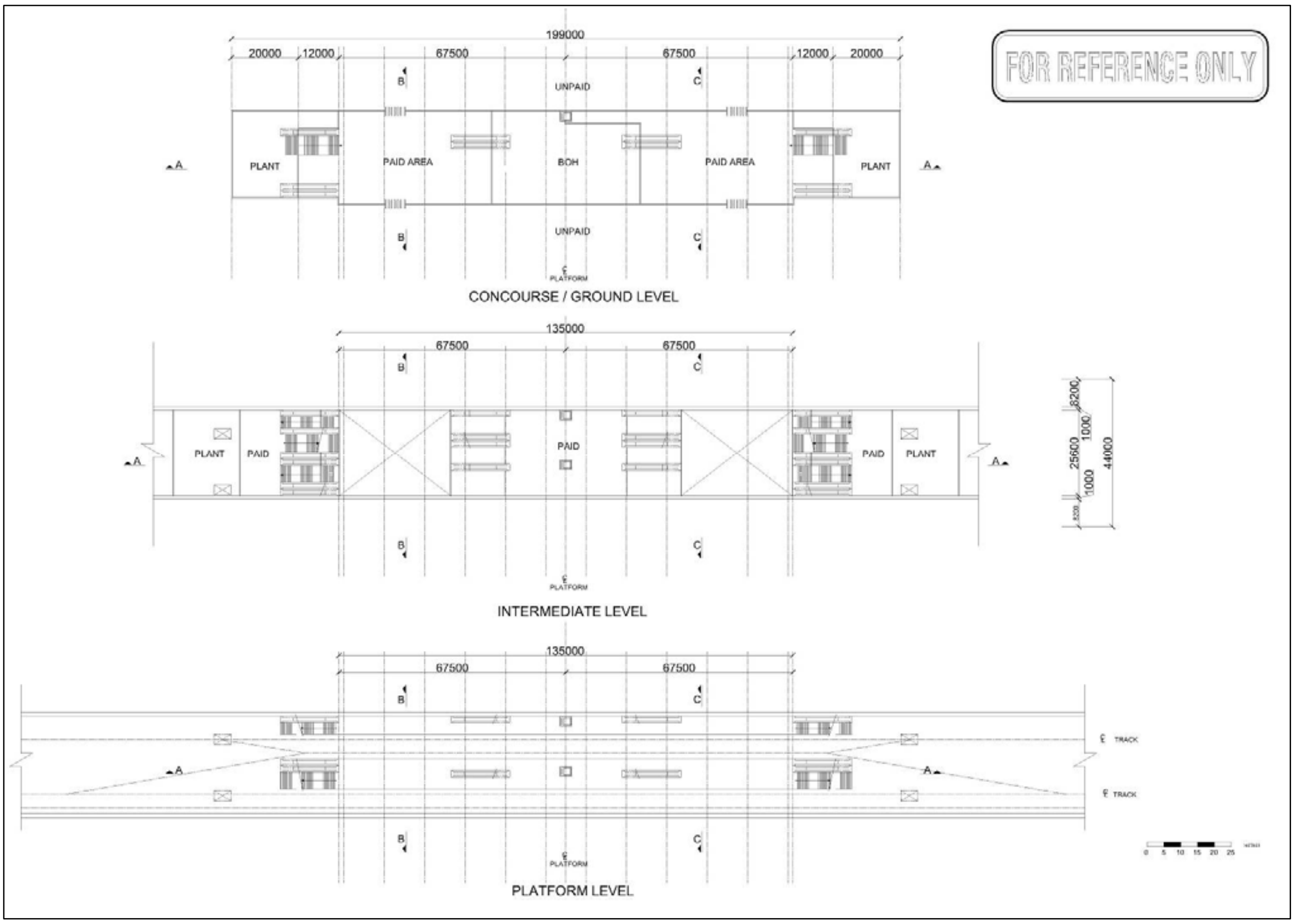
This station shall be located under Ngo Quyen Road at the junction with Ham Long Street.

By locating the station within the road reserve will minimize the potential impact on land acquisition and any resettlement since the road reserve is considered to be sufficiently wide to accommodate construction of the station box. It may be necessary to remove a number of trees in the immediate vicinity to accommodate construction of the station.

The railway will be located within an underground twin tunnel single track system constructed using bored tunnel methodology and therefore minimizing or avoiding any potential disruption or damage to surface infrastructure.

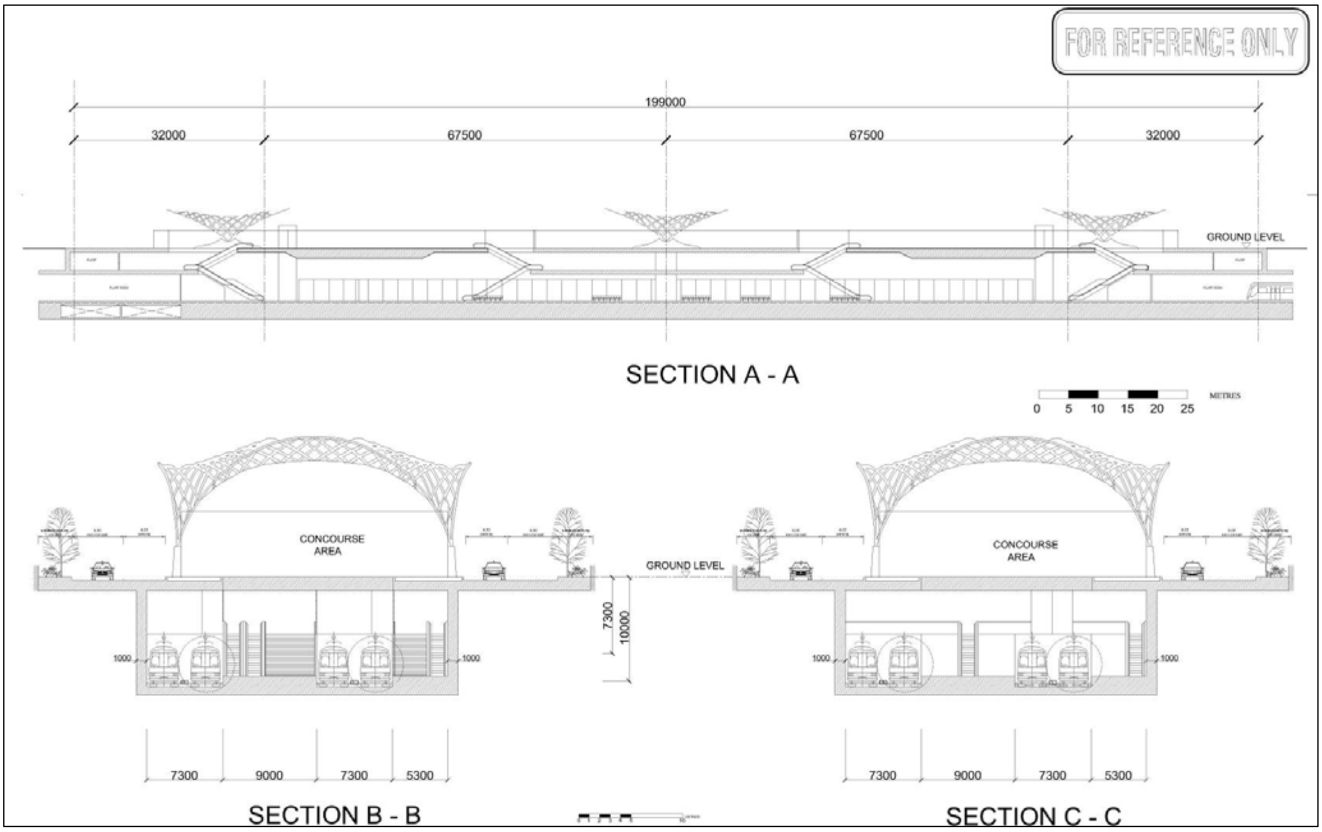
It is anticipated that the station box can be constructed using cut and cover/top down construction techniques within the width of the roadway.

Figure 4.4.2 Tu Liem Station Plan



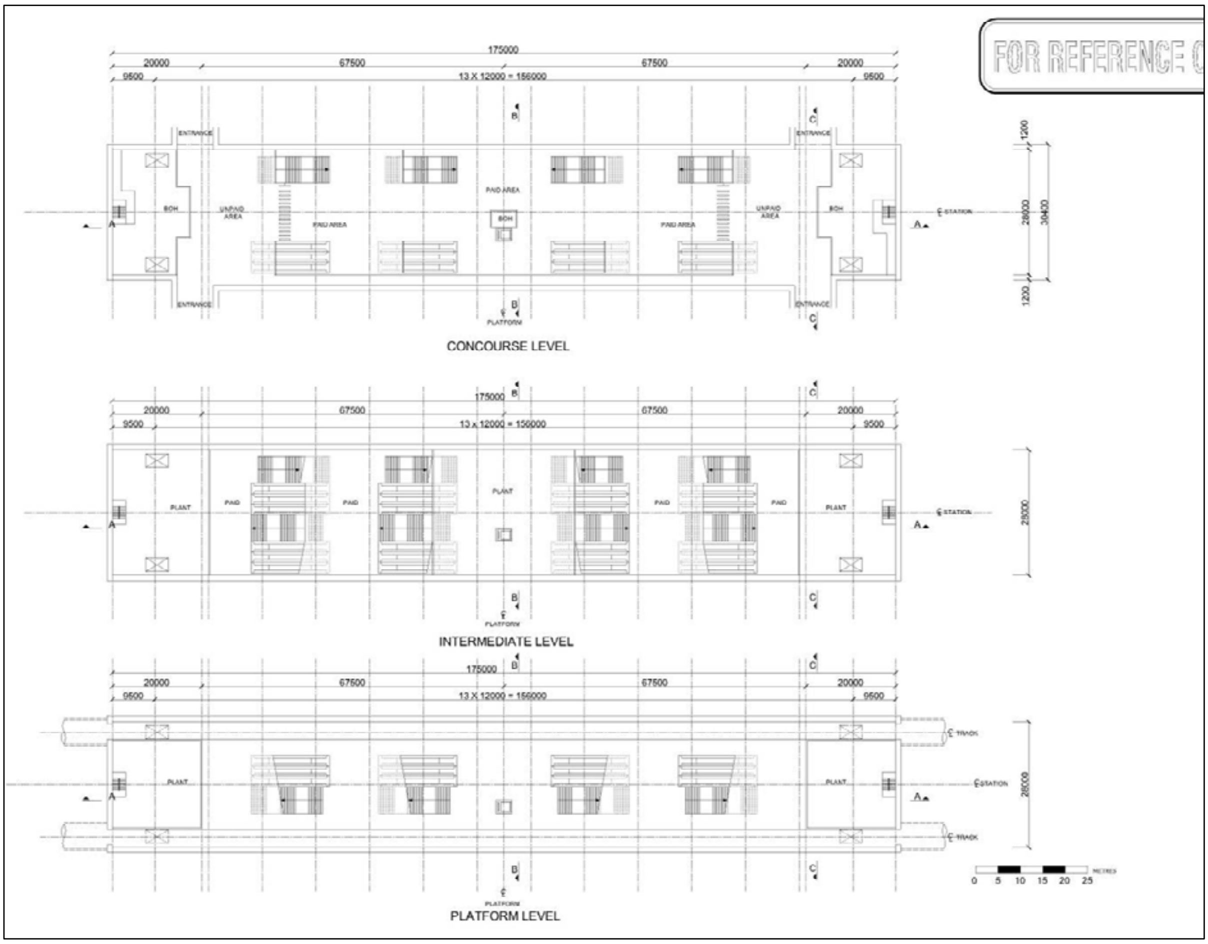
Source: HAIDEP Study Team

Figure 4.4.3 Tu Liem Station Section



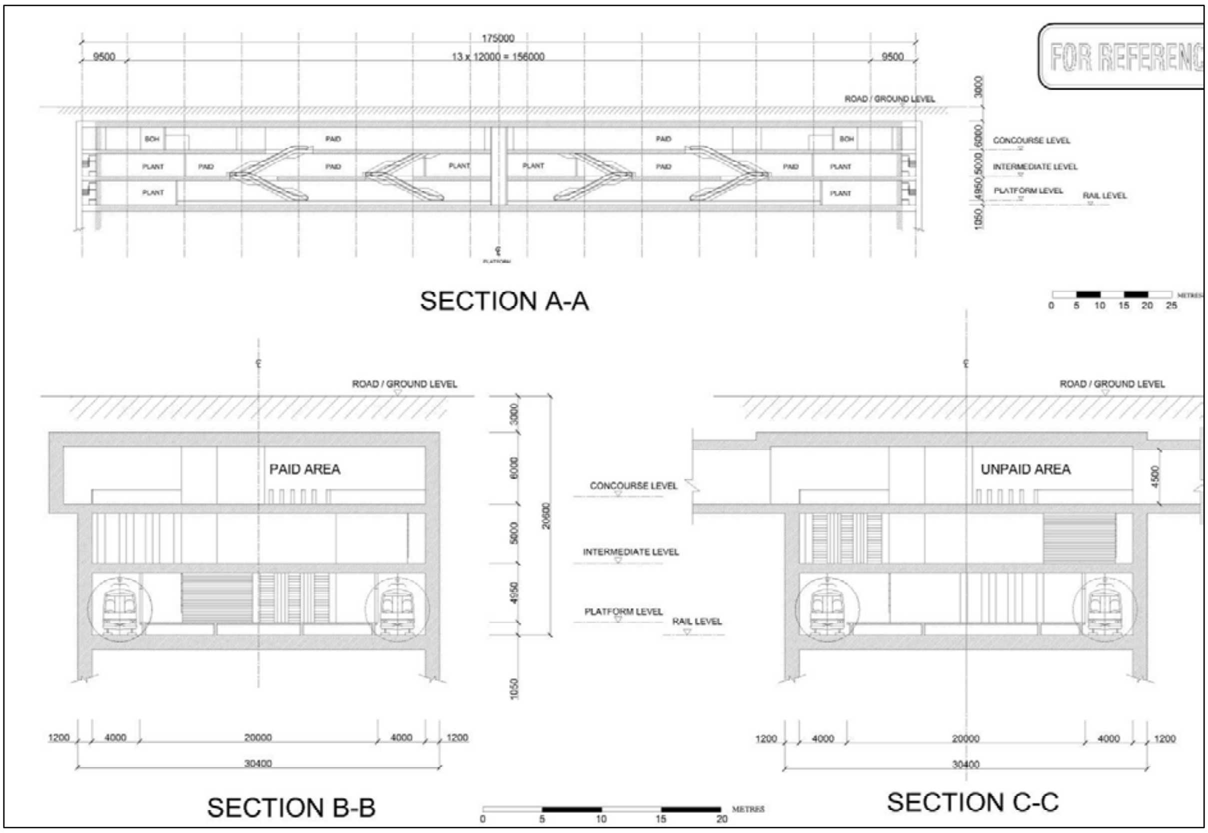
Source: HAIDEP Study Team

Figure 4.4.4 Long Bien Station Plan



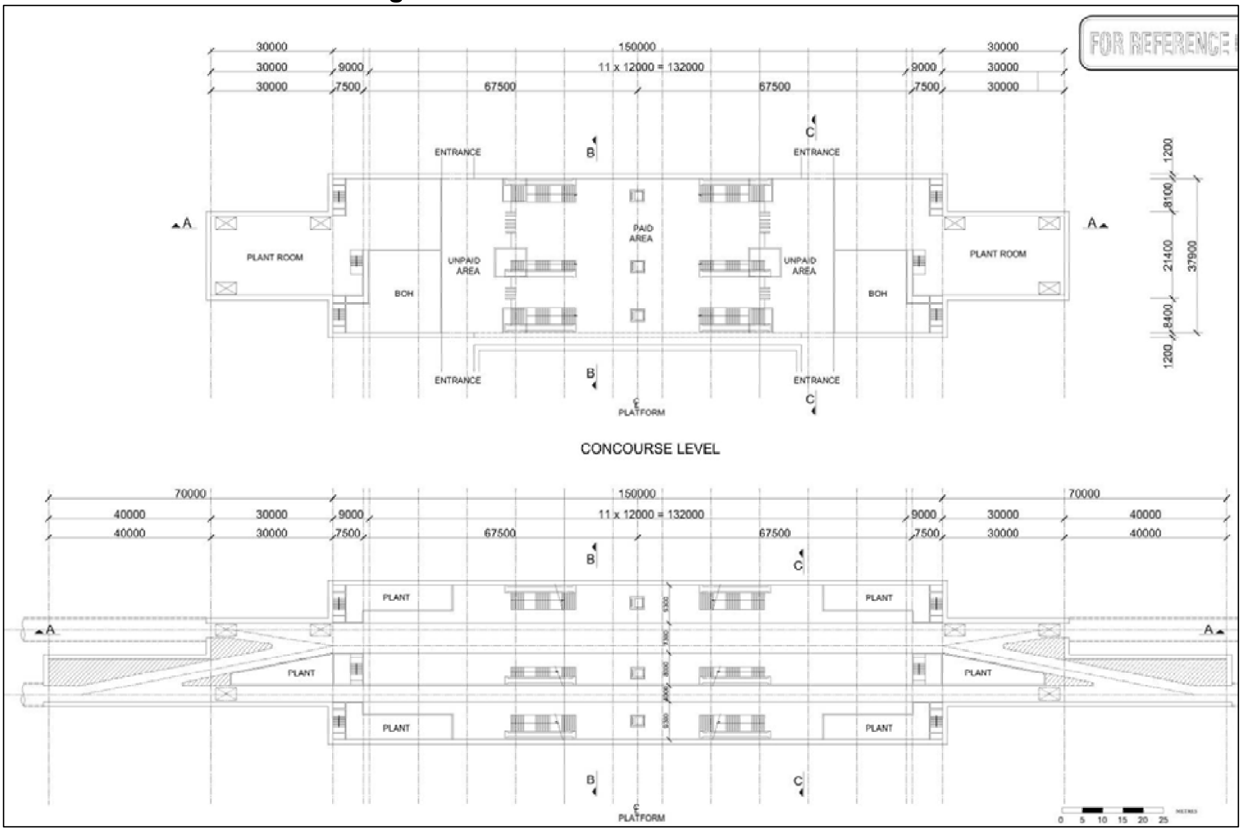
Source: HAIDEP Study Team

Figure 4.4.5 Long Bien Station Section



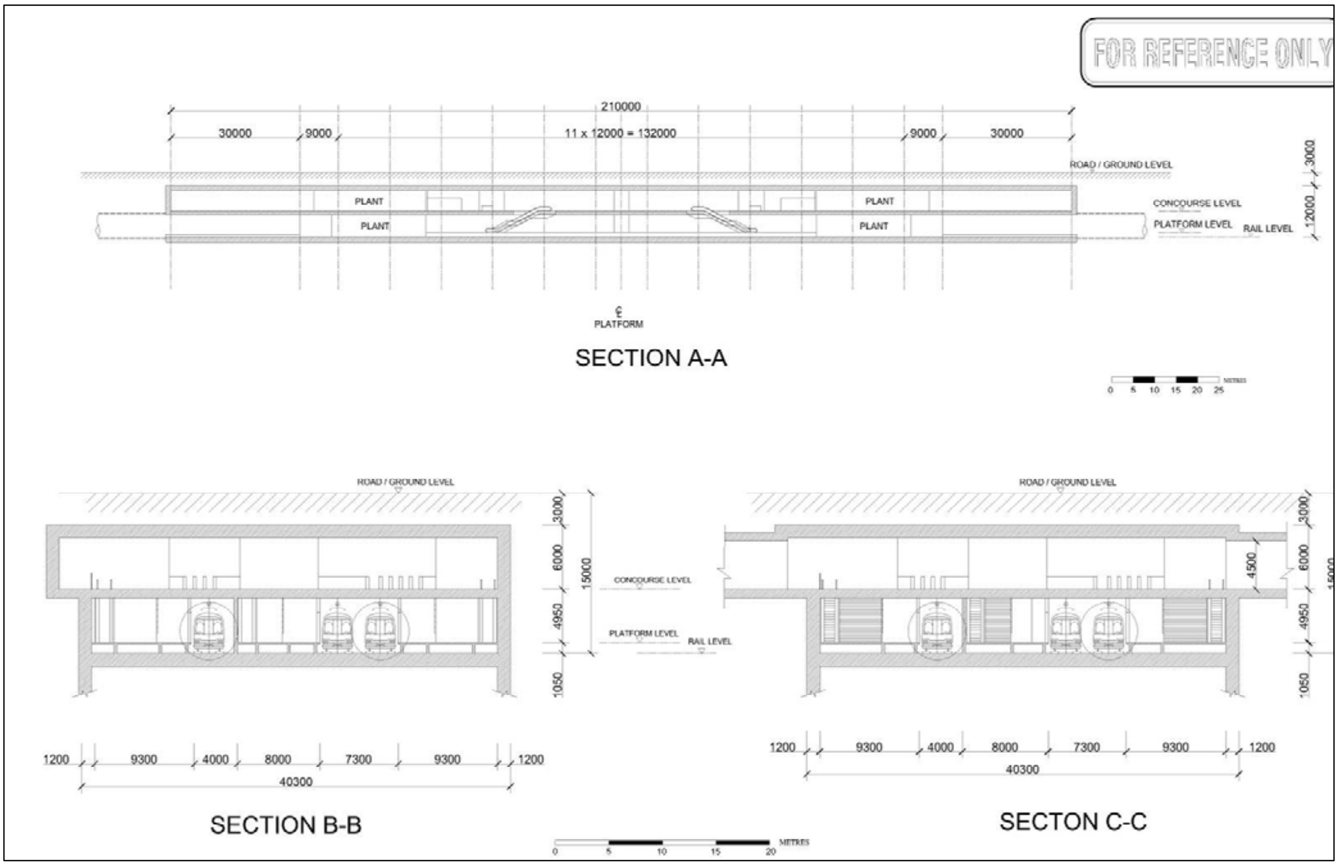
Source: HAIDEP Study Team

Figure 4.4.6 Hoan Kiem Station Plan



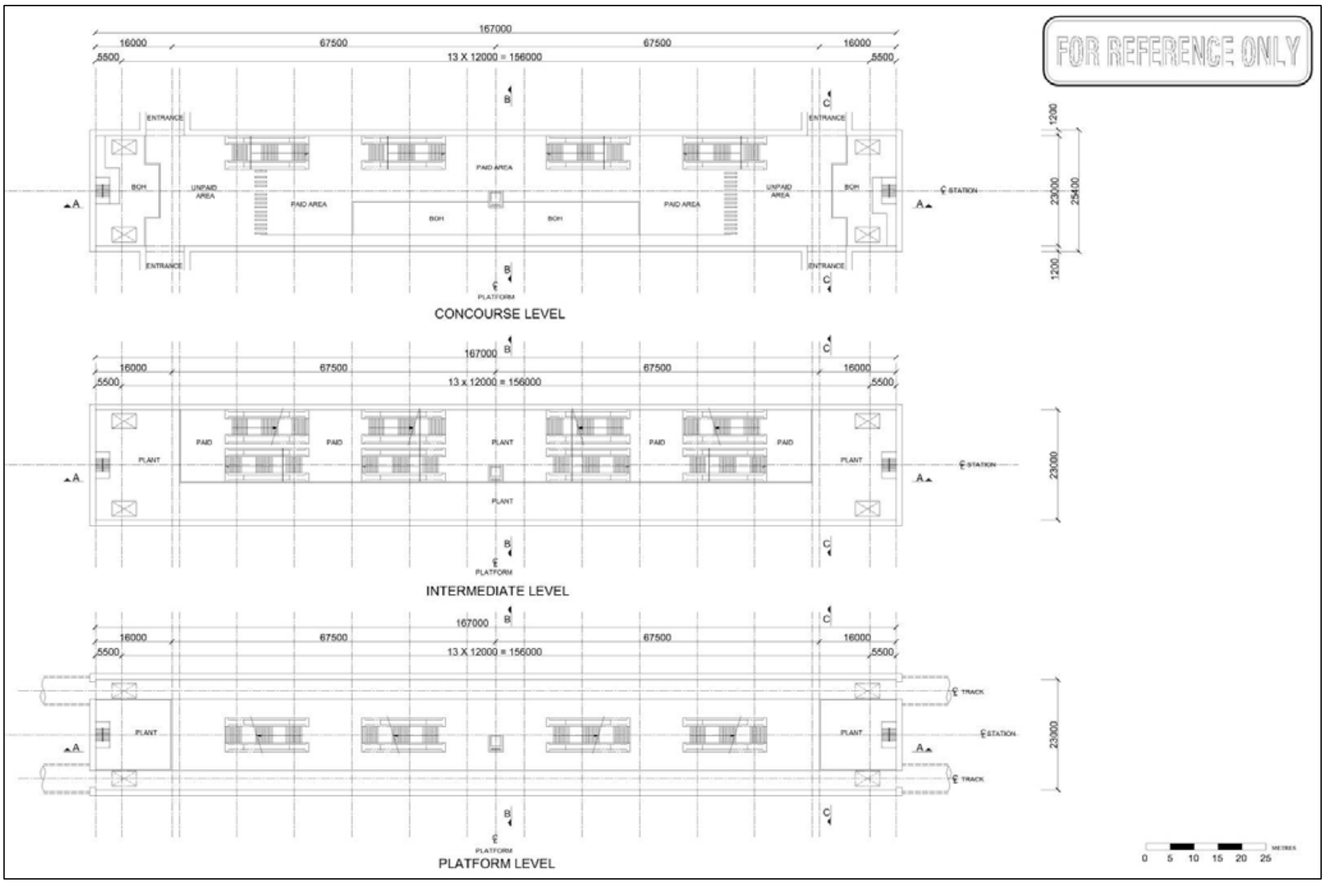
Source: HAIDEP Study Team

Figure 4.4.7 Hoan Kiem Station Section



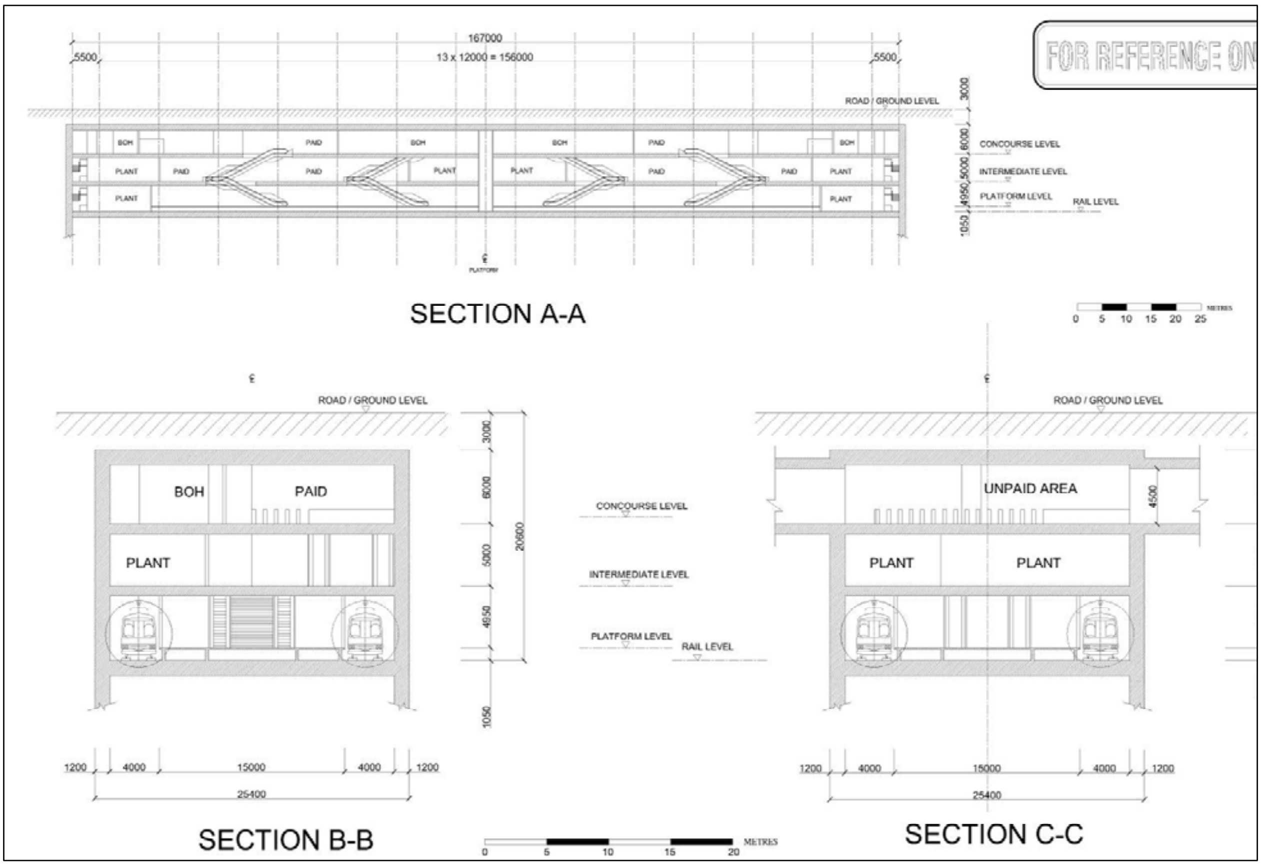
Source: HAIDEP Study Team

Figure 4.4.8 Bac Khoa Station Plan



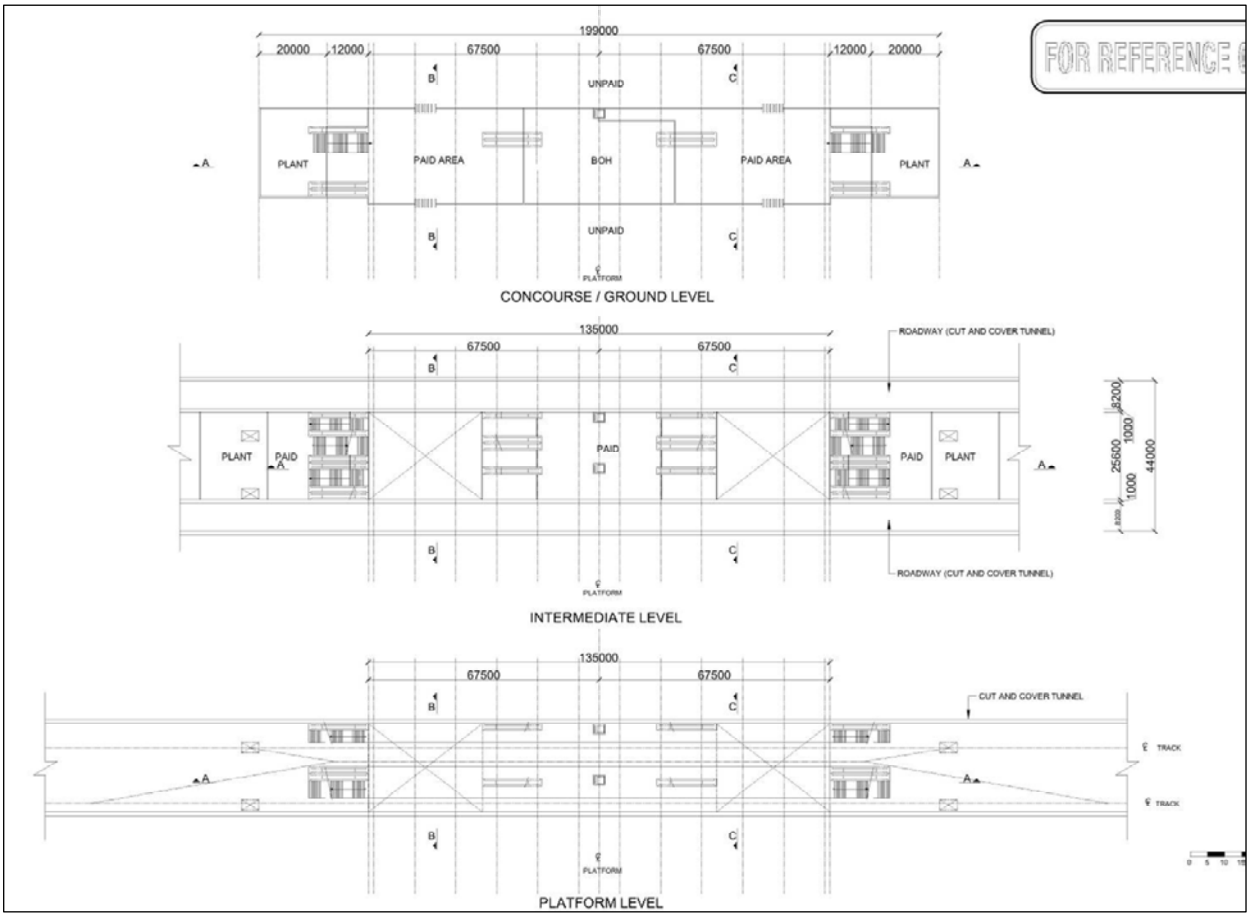
Source: HAIDEP Study Team

Figure 4.4.9 Back Khoa Section



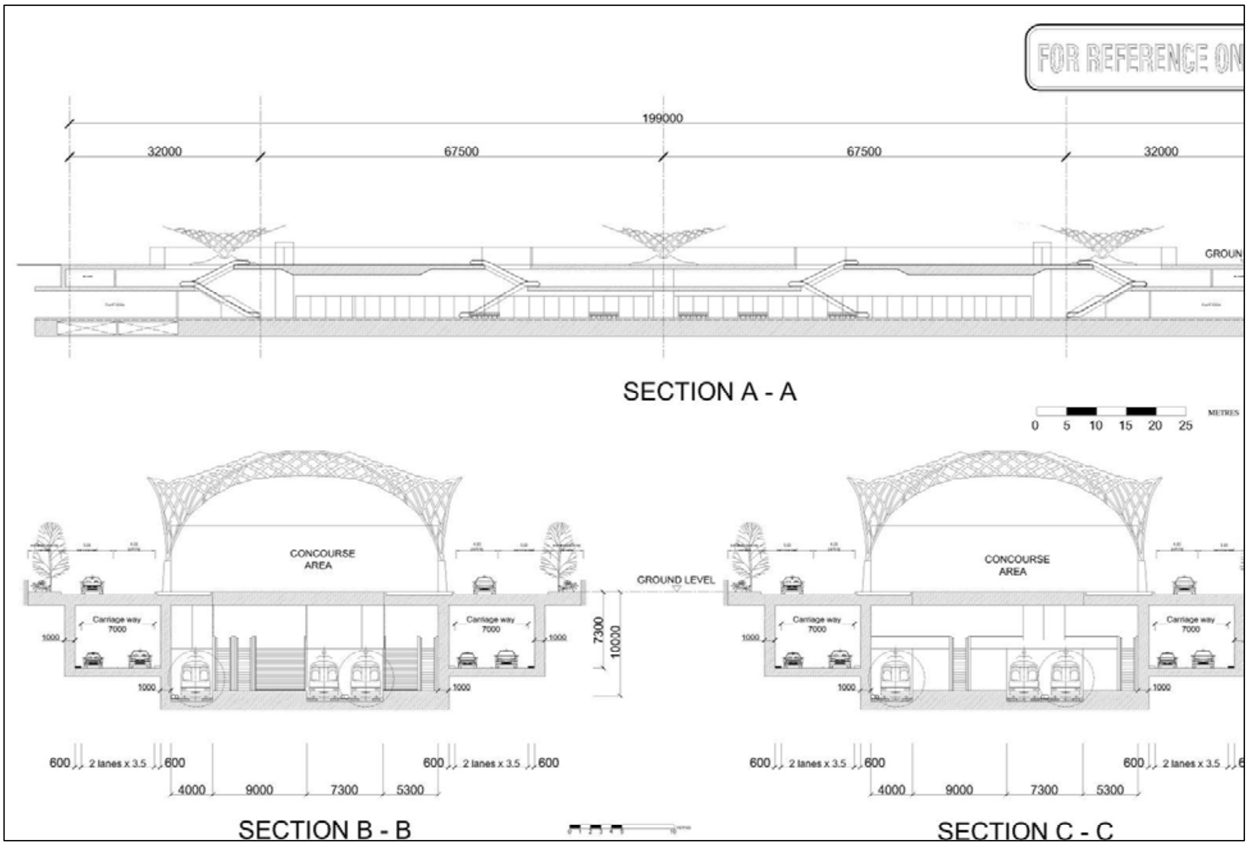
Source: HAIDEP Study Team

Figure 4.4.10 Thuong Dinh Station Plan



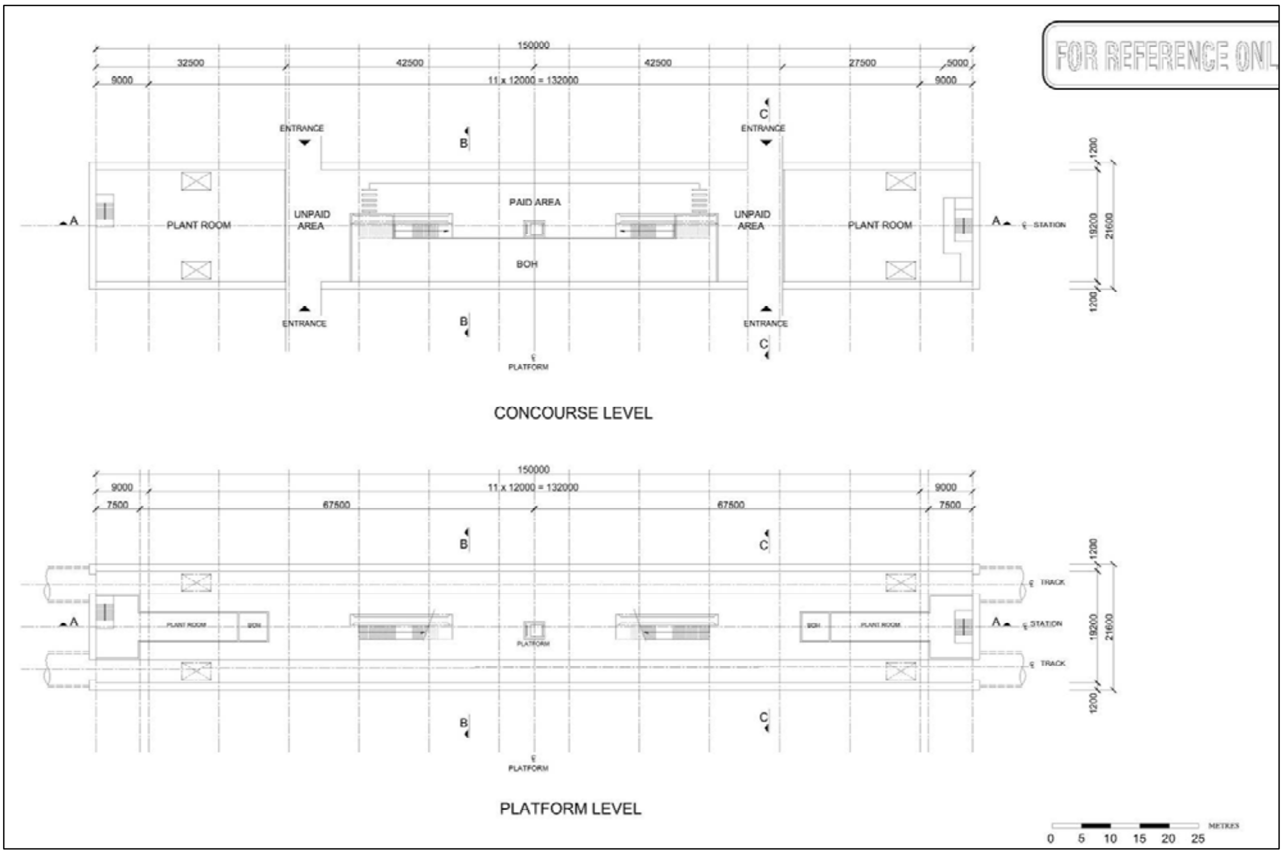
Source: HAIDEP Study Team

Figure 4.4.11 Thuong Dinh Station Section



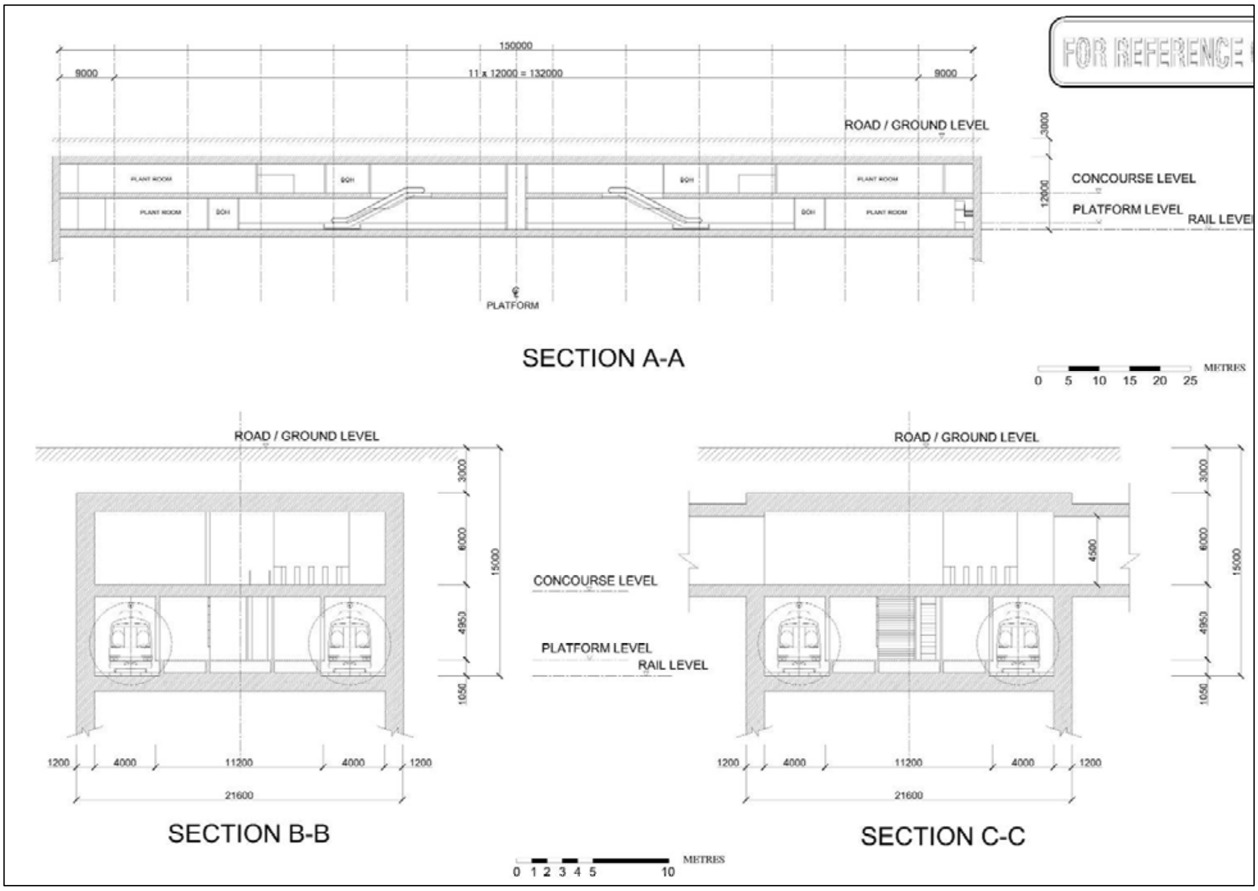
Source: HAIDEP Study Team

Figure 4.4.12 Typical Underground Station Plan



Source: HAIDEP Study Team

Figure 4.4.13 Typical Underground Station Section



Source: HAIDEP Study Team

5 TRANSIT OPERATIONS & MAINTENANCE

5.1 Transit Operations Plan

1) Background

The Master Plan calls for completion of Line 2 by 2020. This will be achieved in phases, in which the first phase, the initial system, would be operational by 2013.

An overview of the projected patronage indicates that by 2040, trains would need to be running at headways less than two minutes and/or be of greater length than a six car formation. It is assumed by then that other transit systems would have been constructed and in operation. This would provide alternative travel options.

The following table indicates the capacity of six car trains at different headways. The assumptions used are that each car has a capacity for design load calculation of 285 passengers. For a six (6) car train, its capacity is 1719 passengers. This represent a six (6) passengers/square meter floor density and a congestion ratio of 180%.

Table 5.1.1 Capacity of a Six-Car Train

Headway	Capacity (pphpd) Passengers/Hour/Direction
2	51,300
2 ¼	45,600
2 ½	41,000
2 ¾	37,300
3	34,200
3 ¼	31,600
3 ½	29,300
3 ¾	27,400
4	25,600

Source HAIDEP Study Team

It will be noted in phases 2 and 3 that before 2040, the two minute headway capacity of 51,300 will be absorbed and trains will at peak times, be relatively overcrowded in some sections. Theoretically, this could be addressed by increasing the length of trains or decreasing the headway, or a combination of both. This is not recommended for the following reasons:

(i) Increasing length of trains makes stations larger and more expensive.

(ii) Decreasing headway, while technically possible, requires more rolling stock.

(iii) Trains can absorb more passengers for short periods (by up to 33% more).

(iv) Passengers will adjust own travel pattern to travel earlier or later.

(v) Ultra peak periods are for short limited periods only.

(vi) Additional transit options will be available.

In order for Line 2 to be cost effective, it is recommended that six (6) car trains form the basis of station design and system design with a minimum headway of two (2) minutes. The six (6) car train length and three (3) minute minimum headways were chosen on the basis of economic sense.

2) Phase 1 (Initial System) Tu Liem to Thuong Dinh

(1) Description

Phase I is between Tu Liem and Thuong Dinh, a route length of around 15km with 14 underground stations. The round trip time is around 55 minutes.

(2) Train Numbers/Headways

Patronage in 2020 is anticipated to be 31,000 passengers per hour per direction (pphpd) at peak times. This will require 17x6 cars trains running at a headway of approximately 3 1/4 minutes. With 1x6 car for maintenance purposes a fleet of 18x6 car trains (108 cars) will be required.

In 2040 patronage will increase to over 46,000 pphpd. This will require 25x6 car trains running at a headway of 2 ¼ minutes. With 2x6 car trains in reserve, a fleet of 27x6 cars (162 cars) will be required.

Table 5.1.2 Number of Trains/Cars

Year	Trains			No. of Cars		
	Operation	Reserve	Total	Operation	Reserve	Total
2020	17x6	1x6	18x6	102	6	108
2040	25x6	2x6	27x6	150	12	162

Source HAIDEP Study Team
Note: Peak hour and off-peak hour services.

Table 5.1.3 Distribution Ratio of Trains by Time Period and Number of Trains (One-Way)

Time		6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
Distribution Ratio		0.5	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
No. of Trains	2020	8	17	17	8	8	8	8	8	8	8
	2040	13	25	25	13	13	13	13	13	13	13
Time Period		16-17	17-18	18-19	19-20	20-21	21-22	22-23			Total
Distribution Ratio		0.5	0.8	0.8	0.6	0.6	0.5	0.3			
No. of Trains	2020	8	14	14	10	10	8	5			167
	2040	13	20	20	15	15	13	7			244

Source HAIDEP Study Team
Note: Ratio used is based on a typical service.

In 2020, 334 trains will be operating each day with the total train kilometers of 5010 per day. This figure is worked out as 167 round-trip trains or 334 trains travel 15 kilometers each trip. Since a train has six cars, the total car kilometers will be 30,060km. The daily car kilometer is worked out by dividing it by 108 cars, which is 278.33km.

By 2040, a total of 488 trains will be operating each day with train kilometers of 7,320km per day. This is calculated as 244 round-trip trains or 488 trains travel 15 kilometers each trip. The total car kilometers will be 7,320kmx6=43,920km. When this is distributed among each car, the daily car kilometers will be 271.11km (43,920/132 = 271.1km). The above figures will be used to determine train energy costs.

3) Phase 1a Tu Liem to Bach Khoa

(1) Description

This is a shortened version of Phase 1 with a route length of around 11.3km with 11 underground stations. The round trip time is 42 minutes

(2) Train Numbers/Headways

Peak hour patronage is the same as Phase 1 at 31,000 pphpd in 2020.This would require 13x6 trains at an headway of 3 ¼ minutes, with 1x6 car in reserve a total fleet of 14x6 car trains(84 cars)

In 2040 19x6 car trains at an headway of 2 ¼ minutes plus 2x6 car trains in reserve a total of 21x6 car trains (126 cars) would be required

4) Phase 2 Nam Thang Long to Ha Dong

(1) Description

Phase 2 is between Nam Thang Long and Ha Dong a route length of around 25.6km with 21 stations. The round trip time is around 92 minutes. Essentially it is an extension of Phase 1, the initial system, North to the Red River (South bank) and South West to Ha Dong, comprising an additional 10.6km and 7 stations.

(2) Train Numbers/Headways

Patronage from Back Khoa to Ha Dong is much lower than the other portions of the route and warrants a less frequent train service. However, this requires train turnaround facilities, which can not be achieved at Bach Khoa due to civil engineering constraints. The turnaround point has therefore been moved to Thuong Dinh. On this basis, alternate trains on the Nam Thang Long to Thuong Dinh portion will run through to Ha Dong at a headway of twice that of the busiest portion.

Patronage in 2020 is anticipated at 34,500 pphpd at peak times Nam Thang Long to Thuong Dinh. This will require a 3 minute headway with 5 minute headways Thuong Dinh to Ha Dong. Train requirements (Phase 1 and Phase 2) are 26x6 car trains, with 2x6 car trains in reserve a total of 28x6 car trains (168 cars).

In 2040, patronage has increased to 52,000 pphph. This will require 2 minute headways Nam Thang Long to Thuong Dinh with 4 minute headway Thuong Dinh to Ha Dong. Train requirements are 39x6 car trains, with 3x6 car trains in reserve a total of 252 cars.

(3) Depot requirements

A depot in the Ha Dong area will be required for stabling light maintenance and cleaning. This is dealt with in more detail under Chapter 5.3 of this report.

5) Phase 3 Thai Phu to Ha Dong

(1) Description

Phase 3 is between Thai Phu and Ha Dong, which is a route length of around 36.3km with 27 stations. The round trip time is around 117 minutes. Essentially it is an extension of Phases 1 and 2, North from Nam Thang Long traversing the Red River to Thai Phu, comprising an additional 10.7km, 6 stations and the Red River tunnel/bridge.

(2) Train Numbers/Headways

In addition to the less frequent service from Thuong Dinh to Ha Dong due to lower patronage as stated earlier, the same applies to the extension North from Nam Thang Long. Trains North from this point have therefore been decreased by 50%, i.e. only alternate trains will travel North of Nam Thang Long. This scenario is quite normal on transit systems with long route lengths. The extremities are often less populated than the core area. Some compensation does however exist in this case since the Phase 3 stations are further apart, less time taken in stopping/starting and station dwell time and longer time at the highest speed. It has been assumed that an average journey speed of 56 kph will be possible against 36 kph used for the other portions of the route.

Patronage in 2020 is anticipated at 38,000 pphpd at peak times in the business parts of the route, i.e. Thuong Dinh to Nam Thang Long. This will require a 2 ¾ minute headway, with 5 ½ minute headways Thuong Dinh to Ha Dong and Nam Thang Long to Thai Phu. Train requirements (Phase I, Phase 2 and Phase 3) are 33 x6 car trains, with 3x6 car trains in reserve a total of 36x6 car trains (216 cars).

In 2040 patronage will increase to 58,000 pphpd. This will require two minute headways Thuong Dinh to Nam Thang Long, with four minute headways Thuong Dinh to Ha Dong and Nam Thang Long to Thai Phu. Train requirements are 45x6 car trains, with 4x6 car trains in reserve a total of 294 cars.

(3) Depot Requirements

A depot in Thai Phu area will be required for stabling, light maintenance, cleaning, etc.

6) Phase 4 Noi Bai International Airport to Ha Dong

(1) Description

This is the full system with an extension of 5.4km from Thai Phu to the Airport. This makes the total route length from Airport to Ha Dong of 41km with a total of 28 stations, 17 underground and 11 at grade/elevated

(2) Train Numbers/Headways

This will require a total of 34x6 car trains at an headway of 2 ¾ minutes (Nam Thanh Long to Thuong Dinh), 5 ½ minutes (Thuong Dinh to Ha Dong and Nam Thanh Long to Thai Phu) and 11 minutes (Thai Phu to Noi Bai Airport) in 2020. With 3x6 car trains in reserve a total fleet of 37x6 car trains (222 cars) will be necessary.

By 2040, patronage will have increased requiring a total of 47x6 car trains at a headway of two minutes Nam Thanh Long to Thuong Dinh, eight minutes Thuong Dinh to Ha Dong and Nam Thanh Long to Thai Phu and eight minutes Thai Phu to Noi Bai International Airport. With 4x6 car trains in reserve a total fleet of 51x6 car trains (306 cars) will be required.

7) Summary of Train/Car Requirements

Table 5.1.4 Train/Car Requirements

Phase	Year	Maximum Capacity (pphpd)	Headway (min.)	No. of Trains			No. of Cars			Remarks
				Service	Reserve	Total	Service	Reserve	Total	
1	2020	31000	3 ¼	17x6	1x6	18x6	102	6	108	
	2040	46000	2 ¼	25x6	2x6	27x6	150	12	162	
1a	2020	31000	3 ¼	13x6	1x6	14x6	78	6	84	
	2040	46000	2 ¼	19x6	2x6	21x6	114	12	126	
2	2020	24500	3	26x6	2x6	28x6	156	12	168	Alternate trains Thuong Dinh to Ha Dong at 6 min headway in 2020; 4 min headway in 2040
	2040	52000	2	39x6	3x6	42x6	234	18	252	
3	2020	38000	2 ¾	33x6	3x6	36x6	198	18	216	Alternate trains Thuong Dinh to Ha Dong and Nam Thang Long to Thai Phu at 5 ½ min headway in 2020, 4 min in 2040
	2040	58000	2	45x6	4x6	49x6	270	24	294	
4	2020	38000	2 ¾	34x6	3x6	37x6	204	18	222	Alternate trains Thuong Dinh to Ha Dong and Nam Thang Long to Thal Phu at 5 ½ min headway in 2020,4 min in 2040 and alternative trains Thai Phu to Noi Bai Airport at 11 mins in 2020 and 8 mins in 2040
	2040	58000	2	47x6	4x6	51x6	282	24	306	

Source HAIDEP Study Team

5.2 Rolling Stock Outline Specifications

1) Rolling Stock Vehicle Options

(1) Car Type

Cars vary from low capacity carrying vehicles e.g. automated people movers, tramcars, to medium capacity e.g. light rail, monorail, to high capacity, so called heavy metro cars as used on many metro systems. The carrying capacities of these are measured in passengers/per hour/per direction (pphpd) in the range of a few thousand up to 85-90,000 pphpd. The patronage projections for Line 2 indicate that in 2020, peak hour ridership will be in the region of 31,000 pphpd and in 2040 at over 58,000 pphpd .Initially the figures place the rolling stock requirements at the top end of light rail capacities and the lower end of heavy metro. Beyond 2020 however patronage will outstrip light rail capacities and for this reason alone heavy metro cars are required.

Further reasons are that on a passenger per unit length basis and in capital cost, a heavy metro car has distinct advantages. A typical metro car is 22 meters long and has a maximum capacity of 380 passengers at maximum crush load. A light rail vehicle for a similar crush load would need to be over 31 meters in length. The reason for this is that they are narrower and for this length, articulated, which takes up space. On a passenger per unit length basis, a metro car is about 30% more efficient. On a vehicle cost basis, a metro car costs around US$1.5 million and a LRT vehicle US$1.9 million. Patently metro cars have benefits.

(2) Train Length and Capacity

Capacity is satisfied by a combination of number of cars and their capacity and the headway, or frequency of trains. Therefore you could have long trains and long headways or short trains and short headways, both would satisfy the same demand. The cost effective solution and to meet the expectations of passengers is to determine the best match between these options.

The range of capacity requirements in 2020 to 2040 is 31,000 to over 58,000 pphpd. Six car trains would meet this capacity during this period at headways between 31/4 minutes and two minutes. These are comparable with other metro systems worldwide. If shorter trains were used the headway would need to be decreased, eventually below two minutes. While this can be achieved, there is little advantage in doing so. If longer trains were used the headway would need to be lengthened but importantly so would the station platform lengths and this has a major effect on capital cost. Overall 6 car trains are seen to be a good match between cost and service, and these are recommended.

2) Rolling Stock Specifications

UMRT Line 2 Rolling Stock shall have the following characteristics:

(i) A safe, reliable, user-friendly and attractive vehicle, with capacity to meet the specified demands and good riding qualities.

(ii) Easy access for physically challenged people.

(iii) Performance shall be designed to meet the limiting gradients and curves in both normal and emergency operation, while optimizing the balance between journey time, total number of vehicles, energy consumption, power supply, and traction equipment.

(iv) High capacity.

(v) Quick and simple detrainment design through both ends of a train.

(vi) High availability of not less than 90% of total fleet with low maintenance costs over their life cycle, low wheel wear, minimum servicing and short down time, based on good diagnostics and minimum component replacement time.

(vii) Ease of exterior and interior cleaning, with low labor contents, and absence of dirt and dust traps.

(viii) Fire hazards, proven non-inflammable, self extinguishing, low smoke and toxicity material to be used.

(ix) Light weight – design to achieve minimum weight consistent with safety and reliability.

(x) Interior finishes pleasing to the eye of appropriate fire resistance standards, which age well and do not date.

(xi) Optimizing the Mean Time Between Failures (MTBF).

(1) Basic Dimensions

(i) The maximum number of passengers to be carried per car is estimated to be 285 (design load[1]) and 375 (crush load).

(ii) Car width 3.1m.

(iii) The car should be aesthetically pleasant to the passengers and should not give a feeling of congestion or suffocation.

(iv) Longitudinal seats will be provided for convenience and space-saving.

(v) There shall be a minimum of four sets of external bi-parting power operated sliding doors per side of each vehicle. The two door panels at each doorway shall be synchronously controlled and shall provide a clear door opening width of not less than 1.4m. To the extent possible, the door pitch shall be equally spaced over the length of a train.

(vi) Occupation density in the standing areas under maximum crush load will be eight persons per square meter and six persons per sq.m. under design loading condition.

(vii) A gangway shall be provided at all non-cab ends of the vehicle. The gangway shall have a minimum width of 1400mm and shall permit passage of passenger's free movement from one adjacent car to another.

(viii) The recommended approximate dimensions of the train car are:

- Length (over couplers) 4 car: 88m
- Length (over couplers) 6 car: 132m
- Width (exterior): 3.1m
- Height from rail level to roof level: 3.8m
- Height from rail level to floor level of empty car with new wheel: 1.10m
- Pantograph height working range: 4.4-6m

[1] The design load equals to a congestion ratio of 180%.

On the basis of the design consideration indicated above, a car of these dimensions should carry about 285 passengers and 375 under crush load conditions as follows:

- An axe load of not greater than 16.5 tonnes is anticipated; and
- A track gauge of 1,435mm is assumed.

The dimensions given above are only recommendations. The overall size shall be optimized to satisfy overall requirements, when there are known.

(2) Performance Parameters

The design of the vehicle shall satisfy the following performance parameters:

(i) Maximum speed:	100 kph
(ii) Maximum acceleration:	1.1 m/sec/sec/sec
(iii) Maximum deceleration (emergency braking):	0.8 m/sec/sec/sec
(iv) Maximum gradient:	3 percent
(v) Minimum horizontal track curvature in depot:	140 meters
(vi) Car internal temperature:	250°C
(vii) Car internal humidity:	65%
(viii) Air circulation rate:	2.66 L/S at 6 pax/m2
(ix) Lighting level:	200-250 lux

(x) Ride quality-to latest ISO 2631 standard or equivalent.

(3) Car Body

The car body shall be of modern light weight construction e.g. stainless steel consistent with strength and safety requirements.

(a) **Doors:** The doors shall be power-operated and their opening and closing will be controlled from the driver's crab. Interlocking will be provided between the doors and the traction control. It is anticipated that at least four doors per side need to be provided consistent with ridership forecasts.

(b) **Car Profile:** The sides should be kept near vertical to permit easy washing with car washing machines. The front of the cars has to be profiled to a shape which, within reasonable costs, will result in lower aerodynamic resistance, and shall be aesthetically pleasing. Various options shall be offered to the client for their determination of final shape and overall style.

(c) **Vehicle interior:** The air conditioning system shall automatically control the temperature and relative humidity throughout the passenger areas up to 250°C and 65% respectively for external ambient temperatures of up to 350°C. At external ambient temperatures above 350°C, a temperature differential of 100°C shall be maintained to prevent passengers experiencing "thermal shock".

(d) **Access for passengers with impaired mobility/physically challenged people:** All vehicles shall be fitted out to satisfy the relevant codes and standards. In addition, all passenger doors each side of each vehicle shall be level +25 mm at all conditions of car loading with the edge of a trackside platform. The gap between the platform edges shall be minimized but shall not exceed 75mm. Safe areas clear of doors and gangways shall be provided for wheelchairs.

(e) **Driving cabin:** Driving cabs will be provided at both ends of the train. The size of the driving cab should be adequate to accommodate all the control equipment. The cab layout should be ergonomically engineered so as to put least strain on the driver. The driving cab shall be air-conditioned to at least the standards in the passenger's saloon area.

(f) **Front doors:** Cabs should have a front door of adequate width to permit frontal evacuation during emergencies. The doors shall also allow for passengers to be safely transferred from one train to another train on the same track. Speed of transfer and simplicity in operation is of paramount importance.

(4) Anti-Noise Measures

(a) **Within car interiors:** Internal noise levels in the passenger saloon, measured with doors closed, the vehicle empty and all equipment operating at maximum capacity, shall not exceed 65 dBA.

(b) **In operation:** In a vehicle traveling at full speed and when the train is operating in any mode of acceleration, deceleration, including friction braking, coasting, with all auxiliary system operating in maximum condition the internal noise level in the passenger saloon shall not exceed 70 dBA.

(c) **Measurements** will be taken 1.2 meters above floor level. Measurements shall not be taken in the gangways connecting coaches.

(d) **Outside car:** Most noise in a moving train on steel rail is generated in wheel-rail contact area, which is transmitted inside coaches and in surrounding areas. The track structure and wheel technology used should be designed with adequate resilience to minimize noise.

(e) **Air-conditioning units:** Noise is also generated by air conditioning units mounted on the exterior (roof) of the car. Care shall be taken to minimize this noise source.

(5) Bogie, Car Suspension and Coupler

(a) **Bogie:** The bogie design should permit the minimum curve to be negotiated safely with least strain on the track structure. This also applies to trackwork in depot areas.Two axle bogies shall be provided and shall incorporate two stages of suspension. The bogie shall be designed for the maximum operational speed. Solid wheels shall be used with around 850mm diameter when new. The maximum permissible static load per axle shall be 18.0 tons.

(b) **Car suspension:** The primary suspension shall be designed to accommodate the appropriate vehicle weight. The secondary suspension shall be pneumatic in operation, with automatic vehicle body to bogie height adjustment function for all vehicle-loading conditions to ensure that the vehicle floor height does not fall below the nominal floor height of 1,100 mm above rail level with the vehicle standing in the station. Safe operation of the vehicle shall be ensured at all operating speeds, in the event that the suspension is deflated. A means shall be provided to adjust the height of vehicle to compensate for any changes resulting from wheel re-profiling, suspension creep or any other relevant factors.

(c) **Couplers:** The car ends dependent upon their type, shall be provided with two types of couplers. The outer ends of the train shall be fitted with automatic couplers, allowing automatic mechanical, electrical and pneumatic coupling and uncoupling of trains. The ends of intermediate cars shall be fitted with semi-permanent couplers. The design of the headstocks shall take into account vertical shear loads and prevent climbing between cars.

(6) Propulsion System

(a) **Traction Motors:** Three phase AC traction motors shall be used. A combination of motor and trailer cars shall be used to achieve performance specifications and lowest energy consumption.

(b) **System of control for traction and electrical braking:** VVVF Controls will be provided using state of the art GTO/IGBT technology.

(7) Braking System

Each car should be provided with the following braking systems namely (1) Electro dynamic brake, (2) Electro-pneumatic brake, (3) Direct pneumatic brake, and (4) Parking brake. Electro-dynamic brakes will be equipped for regenerative braking.

(8) Miscellaneous Equipment in the Car

(a) **Communication:** The cars will be provided with the following communication equipment: (1) Public address system for the train crew to make announcements to the passengers e.g. station names, emergencies, etc. Operational control center should also be able to make announcements directly to passengers; (2) Radio communication between driving cab and the central control; and (3) Telephone communication between the front driving cab and the rear driving cab.

(b) **Auxiliaries:** The Auxiliary Converter shall supply an auxiliary DC and AC voltage as required for the various equipment fitted.

(c) **Lighting:** Car lighting will be recessed fluorescent lamps. The intensity of illumination shall be between 200 and 250 lux. Emergency incandescent lights from the car battery will be provided for emergency lighting in the cars, also for the head lights and tail lights. These should be maintained for at least 60 minutes.

5.3 Depot Requirements

1) Background

To suit the initial system operation of the UMRT Line 2 system, it is proposed to locate the initial depot on a site near the eastern terminal station at Tu Liem. There will be a need for smaller satellite depots and rail vehicle storage areas in later stages of the development of the UMRT Line 2 system located at Ha Dong in the south and Thai Phu in the north.

Analysis of the possible development of Line 2, from the initial system and including various phases and the Airport Express, shows that the number of trains is never likely to exceed around 51x6 car trains, a total of 306 cars, by 2040.

The following table indicates the depot capacity required for the various options, based on the predicted ridership figures, alignment and station details available.

Table 5.3.1 Depot Capacity Required for the Various Options

Phase	2020	2040
Phase 1	18x6 car trains (108 cars total)	27x6 car trains (162 cars total)
Phase 2	28x6 car trains (168 cars total)	42x6 car trains (252 cars total)
Phase 3	36x6 car trains (216 cars total)	49x6 car trains (294 cars total)
Phase 4	37x6 car trains (222 cars total)	51x6 car trains (306 cars total)

Source HAIDEP Study Team

A depot to cater for the full system would not be appropriate for the following reasons:

(i) Too large, difficult to operate;

(ii) Too expensive, would need large land acquisition, in high value land area; and

(iii) Unnecessary, the complete line unlikely to be built simultaneously.

On this premise, more than one depot would be needed, in the future. The first depot should accommodate the early requirements and additional depot(s) planned for the future, on cheaper land further away from the Hanoi City central area.

The depot to be built under Phase I, for the initial system, has been sized to cater for all workshop requirements for Phases 1, 2 and 3 and the airport service.

It is however necessary to have additional satellite depots primarily for stabling, high maintenance and cleaning activities. These can be in areas which land will be cheaper and may become a source of revenue, through property development and attracting additional passengers to the railway. It is recommended therefore that both phases 2 and 3 are built with satellite depots, at Thai Phu and at Ha Dong. There are at or close to the ends of Line 2 which are, in any event, the most practical locations operationally.

2) Depot Size

The first depot should be designed to, at least accommodate the initial system train requirements. On the basis (although unlikely) that further extensions are not built, the size of depot should be capable of accommodating the maximum capacity of the initial system, i.e. 27x6 car trains. This would guard against the unlikely scenario of no further expansion but also keep the land area as small as possible. Apart from this concern, even if extensions are built, the timing of these might not allow the workshop facilities to be built in time for another depot. Therefore workshop facilities should also be accommodated at the first depot and cater for maintenance and overhaul functions, for all systems and equipment. Additionally the depot site should also accommodate the operational control center and administration building.

For the satellite depot, an area of land 110m x 450 m (around 5ha) will be necessary in both locations. During construction this can be used for work areas, particularly at Ha Dong which could be used for Phase I construction; due to its relatively close proximity and lack of suitable sites in the Hanoi central area.

3) Depot Description

To optimize the performance of the trains and infrastructure, and maintain quality and reliability of service, maintenance is of prime importance. The depot maintenance facilities shall be developed with this in mind.

The depot shall provide the requirements for carrying out the following aspects of railway maintenance namely:

(i) Preventive maintenance;
(ii) Light maintenance;
(iii) Heavy maintenance (overhaul); and
(iv) Corrective maintenance.

The size, scope and number of facilities within the depot shall be designed to satisfy the rolling stock fleet initially and in long term. Initially it should accommodate up to 18x6 car trains(108 cars) and be capable to expansion to at least 27x6 car trains(162 cars). Overall the design should be based on 6-car train composition.

Sufficient office accommodation is also required to house the managerial, engineering, and administrative staff necessary to carry out all core maintenance activities, of both the rolling stock and infrastructure. Accommodation is also required for the administrative staff of line 2 and control center staff operating the OCC.

Extensive use of computerized systems to plan work loads, control materials, and stored and inventory, analyze trends in performance of equipment and predict future maintenance requirements is needed.

4) Facilities

Facilities shall be provided for the following:

(i) Passenger rail vehicles-maintenance, stabling and cleaning;
(ii) Civil works including trackwork and inspection of structures;
(iii) Overhead line equipment or third rail traction system;
(iv) Power supplies;
(v) Signaling equipment;
(vi) Telecommunications;

(vii) Automatic fare collection equipment;

(viii) Vehicles including road, road/rail and rail mounted plant and locomotives (if necessary); and

(ix) Information technology.

The depot facilities and stabling area shall be laid out to ensure that maintenance activities can be achieved with the minimum number of movements.

Areas and facilities shall be designed for the following:

(i) Administration offices and staff amenities;

(ii) Stores for light and heavy spares;

(iii) Operational control center;

(iv) Depot sub-station;

(v) Workshop area;

(vi) Maintenance area (to include a depressed floor) and platforms for access to roof and car interior;

(vii) Trackwork equipment and work trains;

(viii) Stabling area;

(ix) Train wash plant (separate track);

(x) Underfloor wheel lathe (separate track);

(xi) Train interior cleaning;

(xii) Dangerous goods store;

(xiii) Storage area for rail; and

(xiv) Emergency diesel generator.

5) Depot Layout

A typical depot layout has been indicated on the attached plans which in addition to the maintenance requirements will include the administration office, operations control room and the main infeed sub station. (See Figure 5.3.1).

Typical plans include:

(i) Track layout;

(ii) Depot roads;

(iii) Depot buildings;

(iv) Typical sections, maintenance and stabling tracks;

(v) Temporary worksite areas during the initial phase construction; and

(vi) Possible commercial development over/adjacent to the depot.

These drawings may be used for planning and budget costing purposes and should be reviewed in some detail during the next stage of development of the UMRT Line 2.

6) Conclusions

The following conclusions were arrived at:

(i) Initial system depot facilities to be located at Tu Liem depot with sufficient space to allow expansion of train capacity up to 2040;

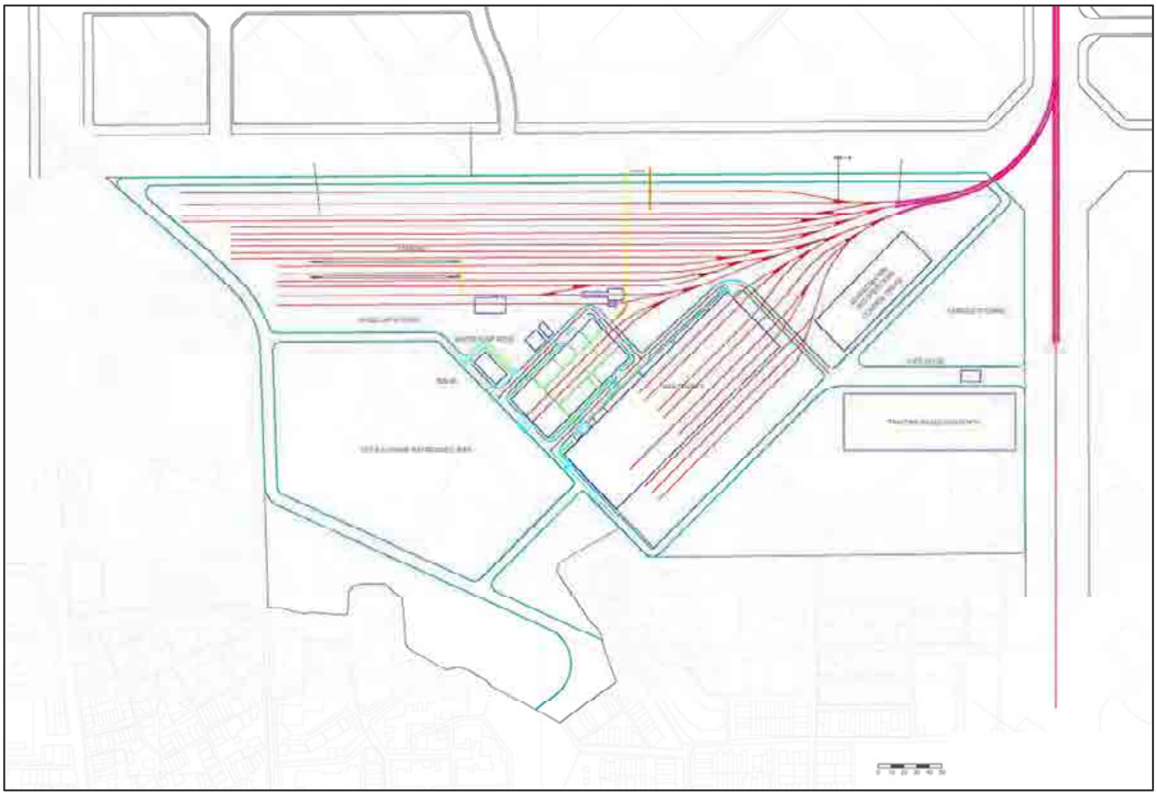
(ii) Facilities to be provided are described in this section;

(iii) Provision to be made for other facilities including railway administration offices, operations control center and infeed substation;

(iv) Space to be provided for temporary worksite for the civil infrastructure and rail systems for the initial system within the site including rolling stock, delivery ,commissioning and testing; and

(v) Depot to be configured to allow for future commercial development above and adjacent to the depot operations and maintenance facilities.

Figure 5.3.1 Tu Liem Deport Plan



Source HAIDEP Study Team

5.4 Operations and Maintenance Organization

1) General

There are many different ways to structure and organize the functions and responsibilities, and the manpower required for the Operations and Maintenance of a rail transit system.

There is no universal structure. It needs to reflect the skills and experience available, the nature of operations, type of service and whether it is a public or private undertaking whatever is chosen needs to embrace all of the functions necessary and in a sensible manner.

Traditionally, railways were operated and maintained by themselves. Increasingly this has changed. It is now quite common for maintenance, in particular, to be outsourced to the private sector, with operations of stations, trains etc. kept with the owner, often a government or public body. This is due to railway suppliers becoming very experienced in maintaining their own equipment, easier access to spares, and being able to call on a wide range of skills, knowledge and experience, often achieved at a lower cost. This is particularly beneficial in countries where experience of modern transit system is non-existent or minimal.

There is a downside to this particular arrangement, since the two major components, operations and maintenance are separated. There needs to be an extremely close working relationship between them, since they both rely on each others efficient and effective actions to achieve successful results.

Whatever institutional arrangements are finally determined, there is a need to keep these aspects well in mind. Irrespective of this the following individual functions are necessary.

2) Functions of the O&M Organization

The following functions are necessary in the set up to operate and maintain a transit system. It is not an exhaustive list but typical of such requirements.

(1) Operations

- Stations
- Trains
- Operational Control Centre (OCC)
- Revenue
- Planning, timetables, rosters etc.

(2) Maintenance

- Rolling stock
- Signaling Control System
- Communication systems
- Traction and Power Supply
- Permanent Way
- SCADA
- Computer services
- Automatic Fare Collection
- Platform Screen Doors
- Fire detection/prevention
- Environmental Control Systems
- Lifts and Escalators
- Depot equipment
- Tunnel Drainage

- Building services, lighting, plumbing etc.
- Civil works

(3) Supporting Services

- Finance
- Contracted out works e.g. cleaning
- Procurement, spares, stores, supplies
- Human Resources, recruitment, training, welfare, salaries and benefits
- Security services
- Safety
- Quality
- Legal and Contractual
- Marketing

(4) Related Services

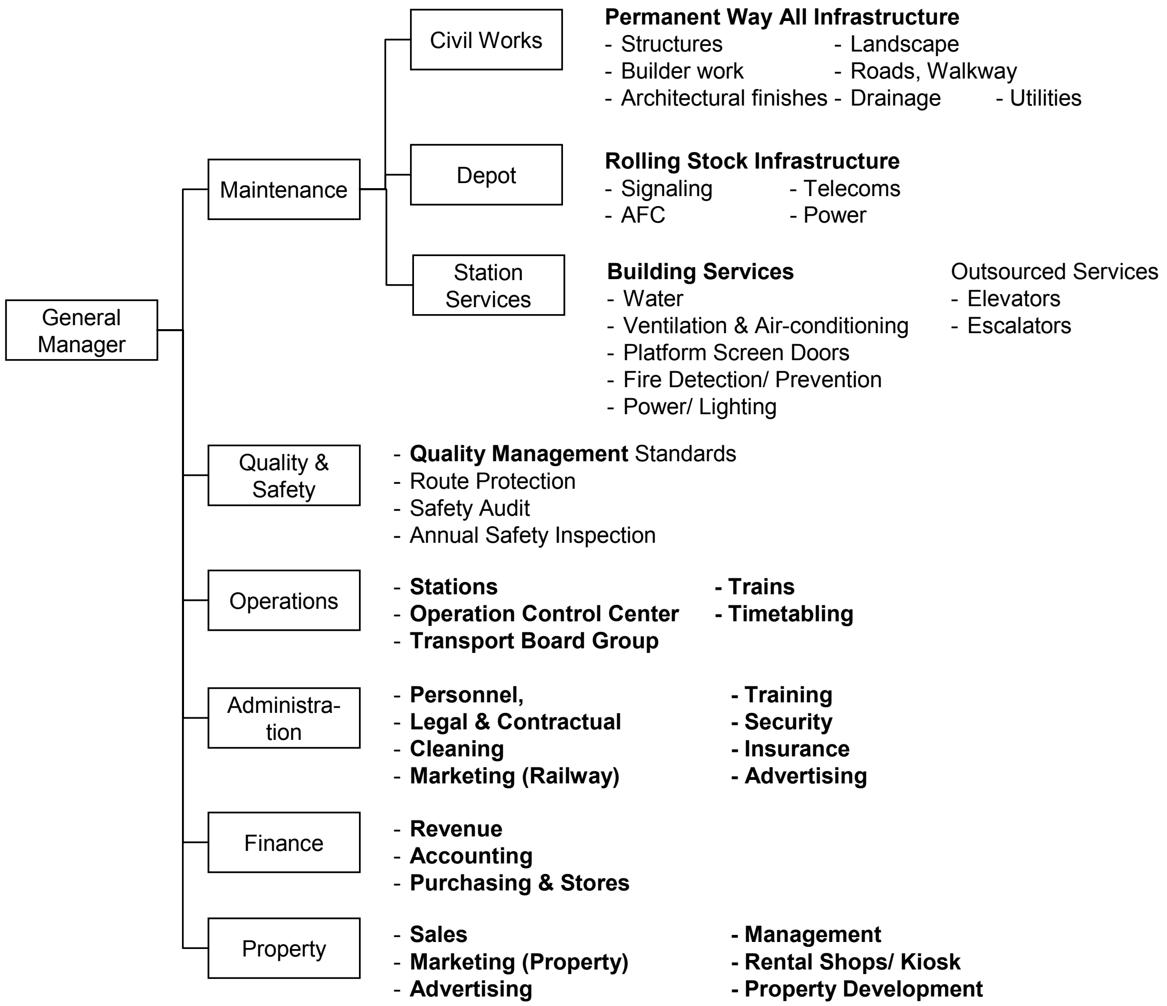
- Non Fare Box revenue, advertising, rentals, leasing shops and kiosks
- Property development and management

3) Typical Organization

The attached organization chart shows a possible way of organizing the various functions. The maintenance organization could be further split. For example, functions under “Depot” might be separated into two groups, rolling stock and railway systems, signaling, telecoms etc. Likewise, Operations could be separated into sub groups of stations, trains, OCC and planning.

It will be noted that Quality and Safety have been given there own department. Safety on any railway is an absolutely pre-requisite and its separation along with Quality is an indication of its importance.

Figure 5.4.1 Typical Organization Chart of O&M Organization



Source HAIDEP Study Team