

Prefeasibility Study B: UMRT Line 2

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AC	Alternating Current
AHD	Above Hon Dau
AFC	Automatic Fare Collection
AG	At Grade Structure
AQ	Ancient Quarter
AQC	Ancient Quarter Conservation
ATM	Automated Teller Machines
ATC	Automatic Train Control
ATP	Automatic Train Protection
B/C	Benefit/Cost
BMA	Bangkok Metropolitan Administration
BMCL	Bangkok Mass Transit Public Company Limited
BOT	Build-operate-transfer
BRT	Bus Rapid Transit
BTSC	Bangkok Mass Transit System Public Company Limited
CBD	Central Business District
CIF	Cost, Insurance and Freight
dBA	Decibels
DC	Direct Current
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EIS	Environmental Impact Statement
EL	Elevated Structure
EPB	Earth Pressure Balance
EPC	Engineering Procurement and Constructing
E&M	Electrical and Mechanical
F-IRR	Financial Internal Rate of Return
FS	Feasibility Study
GoV	Government of Vietnam
GTO	Gate Turnoff
ha	Hectare
HAIDEP	Hanoi Urban Transport Master Plan and Feasibility Study
HCMC	Ho Chi Minh City
HMTA	Hanoi Mass Transit Authority
HPC	Hanoi People's Committee
HPTA	Hanoi Public Transport Authority
KDTM	Old collective housing
kwh	Kilowatt Per Hour
IGBT	Insulated Gate Bipolar Transistors

IRR	Internal Rate of Return
ISO	International Organization for Standardization
JBIC	Japan Bank International Cooperation
Km	Kilometer
Km/h	Kilometer per hour
KV	Kilovolts
LAD	Least Available Depth
LAW	Least Available Width
LTA	Land Transport Authority
LRT	Light Rail Transit
mm	millimeter
MOT	Ministry of Transport
MPMU	Metro Project Management Unit
MPU	Metro Preparation Unit
MTRC	Mass Transit Railway Corporation
MRTC	Mass Rapid Transit Corporation
MRTCL	MTR Corporation Limited
MSTR	Modified Steepest Descent and Relaxation
MTBF	Mean Time Between Failures
Mwh	Megawatt Hour
NCF	Net Cash Flow
NDSM	National Department of Surveying and Mapping
NFPA	National Fire Protection Association
NGC	New Government Center
NH	National Highway
NPV	Net Present Value
O&M	Operation and Maintenance
oC	Degrees Celcius
OCC	Operations Control Centre
ODA	Official Development Assistance
PBT	Priority Bus Transit System
PC	People's Committee
PMU	Project Management Unit
pph	Person Per Hour
pphpd	Passenger Per Hour Per Direction
PSD	Platform Screen Doors
PSD	Particle Size Distribution
SCADA	Supervisory Control and Data Acquisition
SPC	Special Project Company
ROW	Right of Way
rpm	Rotation per minute
SAPROF	Special Assistance for Project Formation
SMRT	Singapore MRT
SOE	State-owned Enterprise
SPC	Special Project Company
TBM	Tunnel Boring Method
TOD	Transit-oriented Development
TTC	Travel Time Cost
UG	Underground Structure
UMRT	Urban Mass Rapid Transit
UPS	Uninterrupted Power Supply
URA	Urban Renewal Agency
USD	US Dollar
V	Volt
VND	Vietnam Dong
VNR	Vietnam Railway
VNRA	Vietnam Road Administration
VOC	Vehicle Operating Cost
VR	Vietnam Railways
VVVF	Variable-voltage Variable-frequency
WB	World Bank

1. INTRODUCTION

1.1 Background and Objective

The purpose of this volume of The Comprehensive Urban Development Programme in Hanoi Capital City (HAIDEP) is to carry out a prefeasibility study into developing an urban mass rapid transit system for the principal transportation corridors identified in the main report from Noi Bai to Ha Dong via the central business area of Hanoi City.

The urban transit project identified in the HAIDEP Master Plan was designated as the Urban Mass Rapid Transit (UMRT) Line 2. The analysis will cover the entire UMRT Line 2, however, special attention was given to the initial phase of development.

The Ministry of Transport and Hanoi City authorities have proposed eight rail routes to serve as the backbone of the public transportation system in Hanoi, in support of the government's policy to expand the role of mass transit in Hanoi. These include:

- (i) Yen Vien-Ngoc Hoi (25km)
- (ii) Hoi-Ha Dong (15km)
- (iii) Bac Co-Hanoi Station-Voi Phuc-Nhon (16km)
- (iv) Hanoi-Noi Bai (25km)
- (v) Daewoo-Trung-Kinh-Hoa Lac (32km)
- (vi) Giap Bat-South Thang Long (19km)
- (vii) Buo-Dong Anh-Soc Son (24km)
- (viii) Co Bi-Gia Lam-Kim No (26km)

In addition, authorities of Vietnam Railway proposed several rail links in the vicinity of Hanoi.

Based on the eight previously identified projects, the HAIDEP master plan consolidated the number of previously proposed (by other studies) lines into four UMRT lines. The UMRT Line 2 will combine the proposed Ha Dong and Noi Bai lines which were identified in previous studies.

Depending on the demand, this line will be a fully integrated rail and bus transit system connecting the fast-developing residential suburbs in the southwest of the city, including Ha Dong, via Ha Noi City's CBD to the proposed new centralized government facilities in Tu Liem onwards to the fast-developing industrial zones on the north bank of the Red River. UMRT Line 2 will also serve the business district of the proposed new towns before it terminates at Noi Bai International Airport.

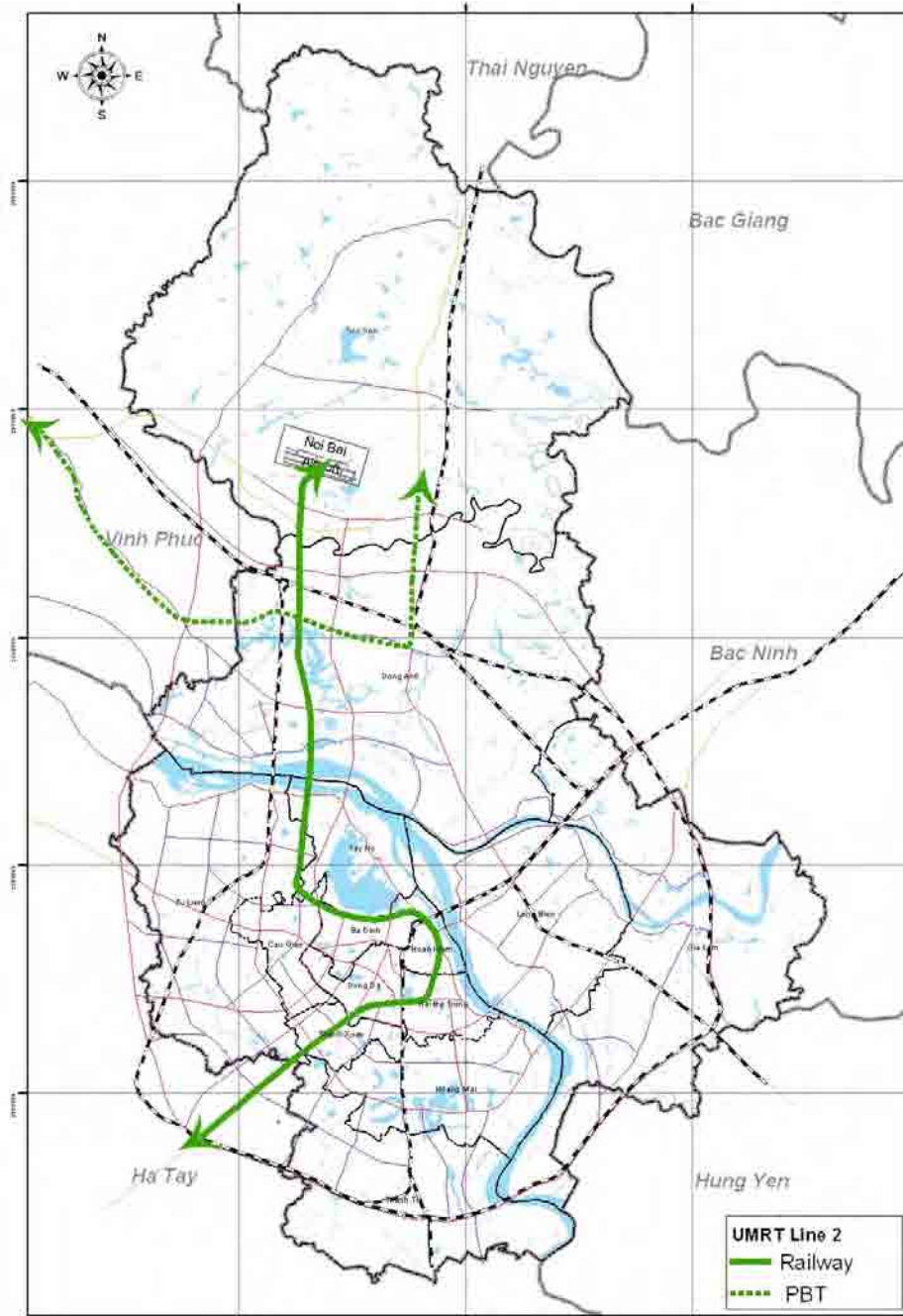
In addition, other new town developments in the north, such as those in Soc Son, will be connected to the northern multimodal hub at Noi Bai with a priority bus transit system (PBT) serving as the northern extension to the UMRT Line 2 system.

It was identified that the corridor will be initially served by a road-based Priority Bus Transit (PBT) system and an associated feeder bus network which could be operational by 2010.

The capacity of UMRT Line 2's initial system will be progressively expanded because the 2013 ridership forecasts indicate that a combined Metro Rail and PBT or bus rapid transit system and supporting feeder bus network will be necessary. To be expanded in particular is the central section of the route between Tu Liem in the north and Truong Dinh in the

south. This expansion is proposed to be the first phase of development of UMRT Line 2. Based on the planning works of HAIDEP, UMRT Line 2 was identified to have the highest potential for development and was therefore selected for prefeasibility study.

Figure 1.1.1 Proposed UMRT Line 2



Source: HAIDEP Study Team

1.2 Report Structure

A brief introduction to the contents of the pre-feasibility study on the development of UMRT Line 2's Initial system follows together with the key issues and recommendations on how to progressively develop a modern, efficient and safe rail based urban mass transit system serving the public transportation corridor including a possible future connection to Noi Bai International Airport.

Chapter 1: Introduction provides the background, objectives and scope of the study on UMRT Line 2.

Chapter 2: Study area conditions describe the climatic and geophysical context of the project.

Chapter 3: Planning issues and the basic concepts for the proposed transit study are described in this chapter. These include traffic demand forecasts and anticipated ridership on the UMRT Line 2 for the design years of 2010 and 2020.

Chapter 4: The engineering aspects of the study are reviewed in here, including an initial assessment of the following issues:

- (i) Engineering Components;
- (ii) Tunnel Construction;
- (iii) Red River Crossing; and
- (iv) Station Design and Construction.

Chapter 5: Transit systems and operations describe the basic transit system operation and provides a first estimate of the number of trains and cars required to operate UMRT Line 2. It also describes the proposed rolling stock, depot facilities and operational and management (O&M) organization.

Chapter 6: Construction method and cost estimate outline the construction program of UMRT Line 2. It shows the estimated cost in constructing and operating UMRT Line 2.

Chapter 7: The environmental and social considerations in the development and operation of UMRT Line 2 are detailed here.

Chapter 8: Recommendations in the implementation arrangements, including institutional aspects are discussed in this chapter.

Chapter 9: Presents the results of the financial and economic evaluation of UMRT Line 2.

Chapter 10: Summarizes the key findings and recommendations of the report.

Appendix: Consists of the illustrations of the key aspects of UMRT Line 2.

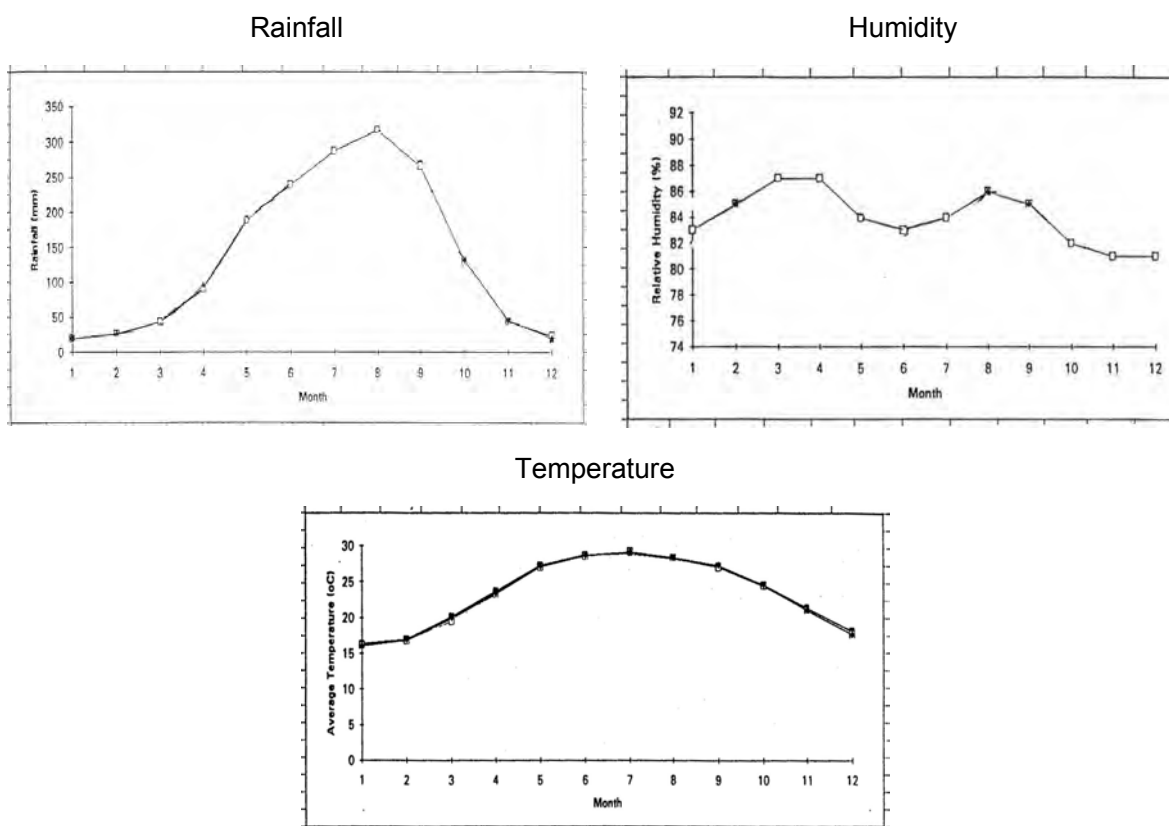
2 STUDY AREA CONDITIONS

1) Climate in Hanoi

In Hanoi, the mean annual rainfall is 1,676mm and the annual mean relative humidity is 84%. Summer lasts from May to September. During this period the mean temperature ranges from 27°C to 29°C with the highest average temperature occurring in July. The highest average rainfall occurs in August (318mm). Winter is from November to March. Both lowest average temperature (16.4°C) and lowest average rainfall (16.6mm) occur in January. Average monthly distributions are shown in Figure 2.1.1.

Every 10 years, on average about 15 typhoons affect the coastal areas to the east of Hanoi. The maximum wind speed recorded is about 180km/h.

Figure 2.1.1 Hanoi Annual Climatic Averages



Source: Statistical Book, Hanoi

2) Topography in Hanoi

According to the National Department of Surveying and Mapping (NDSM) of Vietnam, the zero datum for topographic survey is mean sea level of the tide gauge at Hon Dau (which is 20km south east from Haiphong harbour). Most of the area of Hanoi is at an average elevation of 5m to 20m above mean sea level.

For the remainder of this document, all elevation data refers to the Hon Dau datum, for which the abbreviation AHD (Above Hon Dau) is herein used.

3) Geology and Hydrogeology of Hanoi

The following evaluation is based on the currently limited geotechnical data that is directly relevant to the alignment of UMRT Line 2. During the next stage of UMRT Line 2, a detailed and comprehensive geotechnical site investigation programme will therefore be required in advance for the design.

During the period 14 February to 4 March 2006, 12 drill holes were drilled in the central area of the route of UMRT Line 2. Laboratory testing of samples from these drill holes was undertaken during 18 February to 11 March 2006.

Based on this limited information, a rough geological long section has been prepared and is presented on Figure 2.1.2. A summary of the geology and hydrogeology is presented in Table 2.1.1 and a summary of the geological formations and geotechnical characteristics is presented in Table 2.3.2.

Table 2.1.1 Geology of Hanoi

Formation	Description	SPT	Hydrogeology
Holocene (the last 10,000 years)			
Thai Binh 3-4	Alluvial Clay, Clayey Silt	5 to 6	
Thai Binh 1-2	Loose to Medium Dense Alluvial Sand and Silty Sand	6 to 15	Unconfined Aquifer recharged by surface and river infiltration. Poor water quality. Medium to high permeability
Hai Hung 2-3	Marine Clay, Silty Clay	6 to 15	Low permeability
Hai Hung 1	Lacustrine -swamp Silty Clay	2 to 4	
Pleistocene (10,000 to 1.65 million years ago)			
Vinh Phuc 4	Not encountered	-----	Low permeability
Vinh Phuc 3	Very Variable Alluvial Lacustrine Silty Clay	7 to 12	
Vinh Phuc 2	Alluvial Clayey Silty Sand with some lenses of Dense to Medium Dense Gravel	15 to 30	Primary Aquifer for domestic water supply in Hanoi. Recharged by Red River High permeability
Vinh Phuc 1	Alluvial and Proluvial Dense to Very Dense Gravel and Cobbles with some Clayey Silt	30 to over 50	
Hanoi	Alluvial Very Dense Cobbles and Gravel mixed with Silty sand and occasional Stiff Sandy Clay. Known to be up to 65m thick in Hanoi	Mostly over 100	

Source: Various sources

In the 12 drill holes, the standing water level varied from a depth of 1.2m to 10m, and averaging 4.5m below ground level. The equivalent elevation range is from -1.3mAHD to 6.5mAHD; wherein the average is 3.55mAHD. However, since the Thai Binh 1-2 Formation is an unconfined aquifer and on the other hand, the Vinh Phuc 2, Vinh Phuc 1 and Hanoi Formation group is a confined aquifer, where these formations are all encountered in the same drill hole, the standing water level is probably representative of the combined effect of both aquifers.

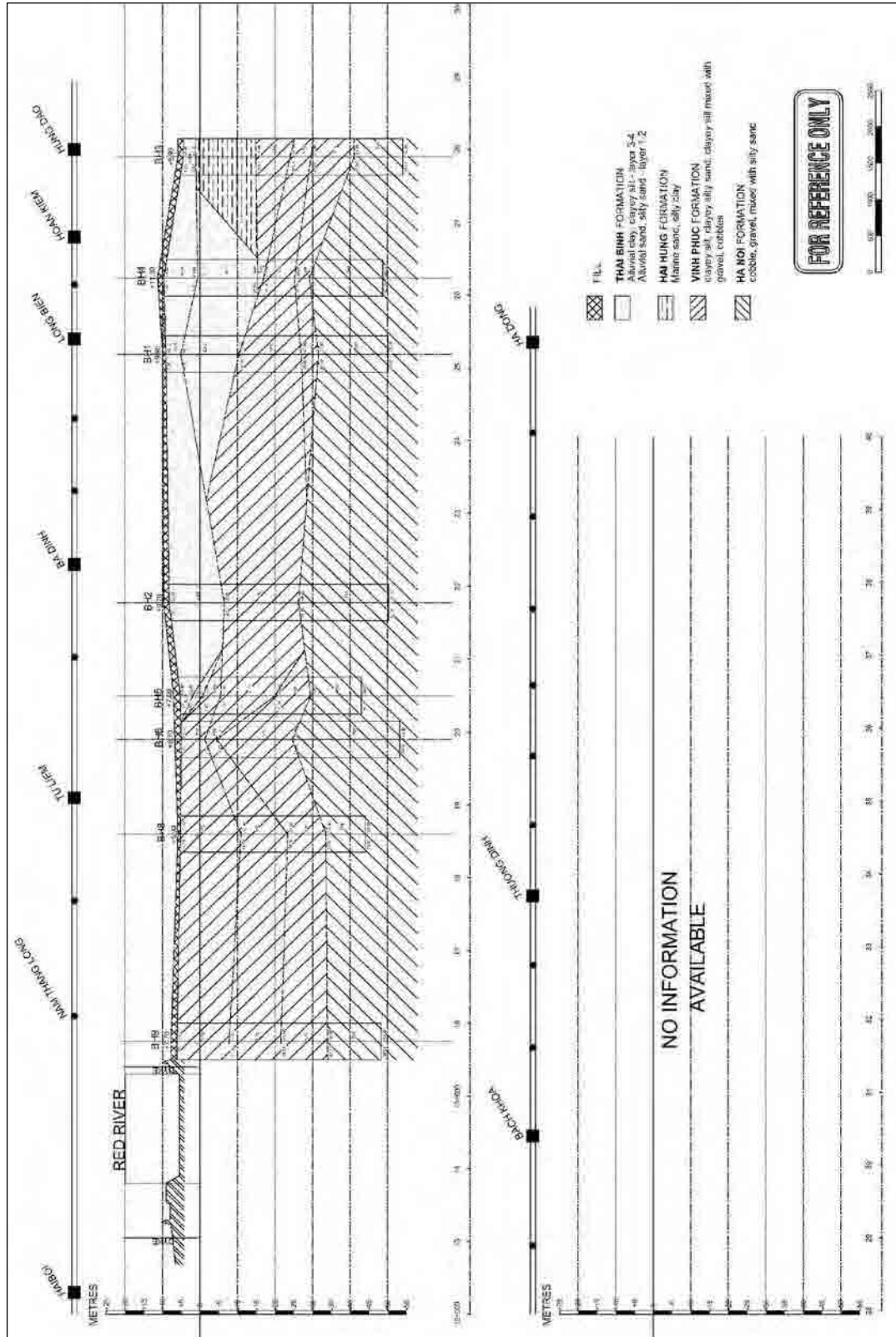
Table 2.1.2 Summary of Drill Hole

Eh	Ground Level X	Y	Water Level	Water Depth	FILL			THAI BINH 3-4			THAI BINH 1-2			HAI HUNG 2-3			HAI HUNG 1			VINH PHUC 3			VINH PHUC 2			VINH PHUC 1			HANOI			
					Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	Thick	Base Level	Depth	
1	9.9		0.6	9.3	0.8	9.1	0.8	4	5.1	4.8	15.5	-10.4	20.3									16.6	-27	36.9	4.6	-31.6	41.5	18.5	*	60		
2	9.7		6.5	3.2	1.5	8.2	1.5	15	-6.5	16.2												19.8	-26.3	36				24	*	60		
3	5.9		1.3	4.6	1.5	4.4	1.5	3.3	1.1	4.8				1	0.4	5.5	15	-14.9	20.8	9.2	-24.1	30	5.5	-29.6	35.5	11	-40.1	46	14	*	60	
4	11.3		4.8	6.5	1.7	9.6	1.7	9	0.6	10.7	16	-15.4	26.7								1.6	-17	28.3	8.2	-25.2	36.5	4	-29.2	40.5	19.5	*	60
5	7		5.2	1.8	1.7	5.3	1.7	3.3	2	5	2.8	-0.8	7.8								4.7	-5.5	12.5	14.5	-20	27	9.5	-29.5	36.5	23.5	*	60
6	6.7		5	1.7	1.7	5	1.7														6.3	-1.3	8	3.2	-4.5	11.2	20	-24.7	31.4	28.6	*	60
7	7		4.3	2.7	2	5	2														22	-17	24	4.1	-21.1	28.1	5.4	-26.5	33.5	26.5	*	60
8	5.9		4.7	1.2	0.7	5.2	0.7														13.1	-7.9	13.8	15.5	-23.4	29.3	10	-33.6	39.5	10.5	*	50
9	7.7		6.3	1.4	1.6	6.1	1.6														13.9	-7.8	15.5	13.6	-21.6	29.3	12	-34	41.7	14.3	*	56
10	8.7		-1.3	10	0.5	8.2	0.5	9	*												9.5	*	10									
11	7.5		3	4.5	1	6.5	1			10																						
12	8.7		2.2	6.5	0.5	8.2	0.5														9.5	*	10									
AVERAGE			3.55	4.45	1.27	6.73	1.27	6.9	0.46	8.3	11.4	-8.87	18.3								10.1	-11.5	18.9	11.2	-22.6	29.98	9.6	-31.2	36.83	19.9333		
MAXIMUM			6.5	10	2	9.6	2	15	5.1	16.2	16.2	-0.8	26.7								22	-1.3	30	19.8	-4.5	36.9	20	-24.7	46	28.6		
MINIMUM			-1.3	1.2	0.5	4.4	0.5	3.3	-6.5	4.8	2.8	-15.4	7.8								1.6	-24.1	8	3.2	-29.6	11.2	4	-40.1	31.4	10.5		

Alluvial, clayey, silt SPT 5 to 6	Loose to Medium Dense Alluvial Sand and Silt Sand 6 to 15	Marble Clay, Silt Clay 6 to 15	Lacustrine-Swamp Silt Clay 2 to 4	Very Variable Alluvial Lacustrine Silt Clay 7 to 12	Alluvial Clayey Silt Sand with some Lenses of Dense to Medium Dense Gravel 15 to 30	Alluvial and Proluvial Dense and Very Dense to Gravel and Cobbles with some Clayey Silt 30 to over 50	Alluvial very Dense Cobbles ad Gravel with Silt sand and occasion stiff Sandy Clay. Known to be up to 65 m thick in Hanoi Mostly over 100
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Source: HAIDEP Geotechnical Investigation

Figure 2.1.2 Geological Long Section

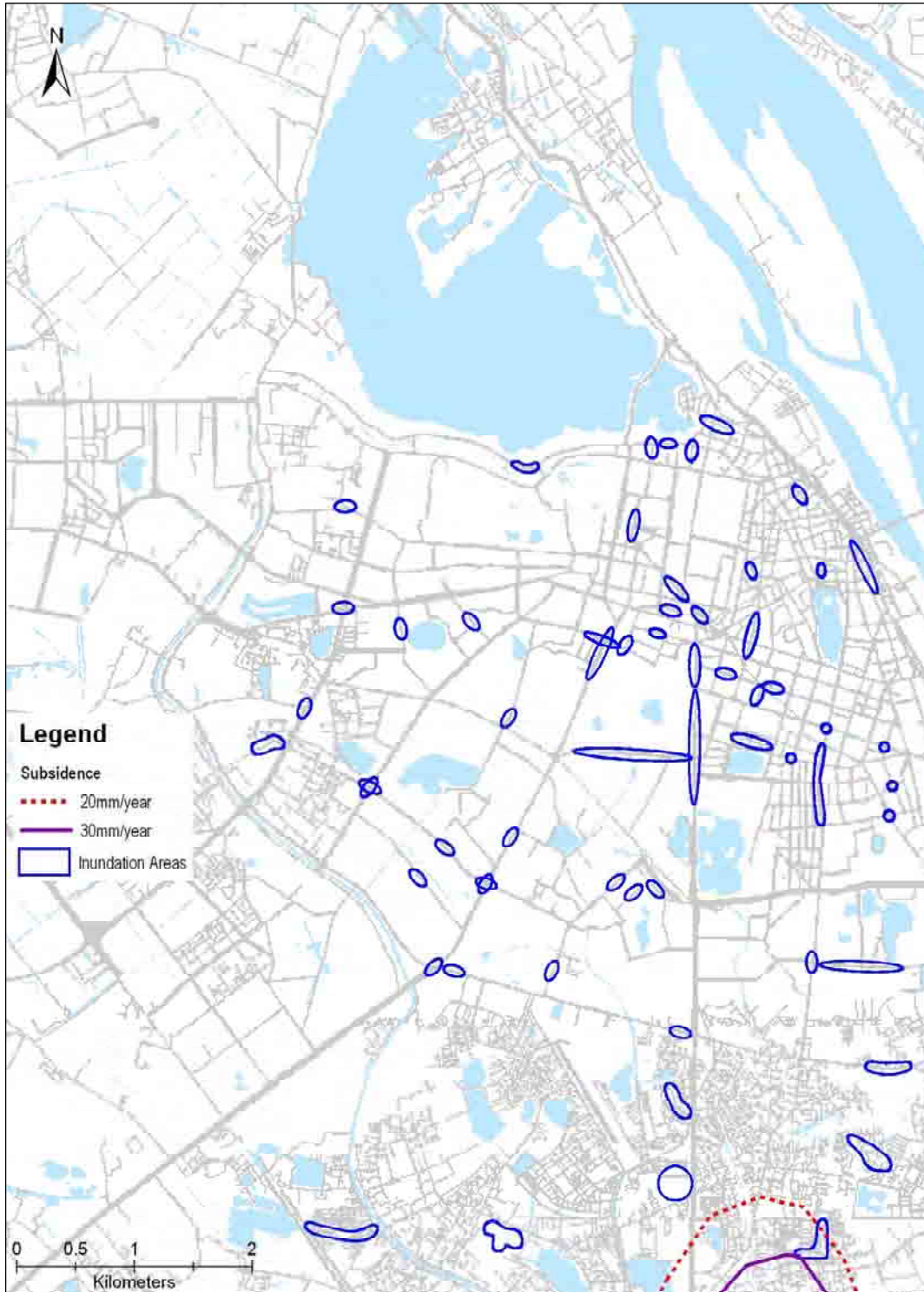


Source: HAIDEP Geotechnical Survey

4) Inundation and Subsidence

Hanoi experiences flooding due to rains at certain areas in the city, primarily as a result of poor and insufficient drainage system. Moreover, land subsidence is a growing issue, as excessive ground water extraction continues as alternative water supply sources have not been developed yet. Inundation areas and subsidence areas on the UMRT Line 2 corridor is illustrated in the Figure 2.1.3.

Figure 2.1.3 Inundation and Subsidence Areas Along UMRT Line 2 Corridor



Source: Hanoi Drainage Project for Environmental Improvement, JBIC

5) Earthquake Risk in Hanoi

According to a technical paper by Nguyen Hong Phuong published in 2004, in Vietnam, despite the fact that events of magnitude 6.7 or higher have historically occurred in the north western part of Vietnam, earthquakes have never been recognized in Vietnam as a disaster of highest priority. Nguyen suggested that to some extent, this is because the earthquakes that have occurred in recent times were not devastating partly because their epicenters were located far from the urban or industrial areas.

Still, given the nature of the near surface geology in Hanoi, liquefaction of the alluvial silts and sands is a risk that needs to be taken into account in any earthquake assessment associated with new construction. Consequently, as theoretical exercise, Nguyen undertook an earthquake risk and damage assessment of the Hoan Kiem District of Hanoi. This analysis suggests that there would be significant potential for damage.

It is therefore apparent that an appropriate earthquake design standard needs to be considered as part of the design of the UMRT Line 2. It is understood that historically, the lowest seismic zone of the old (i.e. pre 2001) Russian Seismic Building Code was used as the basis of design.

6) Implications of the Existing Foundation Interaction

High rise buildings (i.e. greater than 10 stories) are a relatively recent occurrence in Hanoi (within the last 15 years). There are currently less than 50 buildings in the range of 12 to 27 stories. Foundation types used in Hanoi is indicated in Table 2.1.3.

Table 2.1.3 Foundation Types Found in Hanoi

Bamboo Piles	Hand driven, very closely spaced, depth 3m to 5m. Still used today.
Brick Strip Footings	Nature, depth and extent generally unknown.
Wood Piles	Driven, depth unknown. Wood Piles at Hanoi Opera House are 200mm to 300mm diameter.
Driven Piles	Used in the early 1970's but driving caused excessive damage and settlement to adjacent buildings. Understood no longer permitted.
Press Piles	150mm to 300mm square section concrete piles, each section about 1.5m long. Pushed into the ground by hydraulic jack frame. Sections added by tack welding and pushed into ground until refusal. Could be up to about 20m deep. Usually combined with concrete base slab with integral beams. Load capacity per Press Pile of order 650kN.
Bored Piles	Now commonly used for high rise buildings. Up to 1.2m diameter, supported by casing for say first 5m then remainder by bentonite slurry. Founded on the Hanoi formation.

Source: HAIDEP Study Team

Thus the majority of the existing low rise buildings in Hanoi which was built pre-1980 are probably constructed on bamboo piles or shallow brick strip footings, founded on/in alluvial clays and silts. Consequently, there is significant potential for these older structures to be adversely affected by settlement caused by adjacent excavation and vibration.

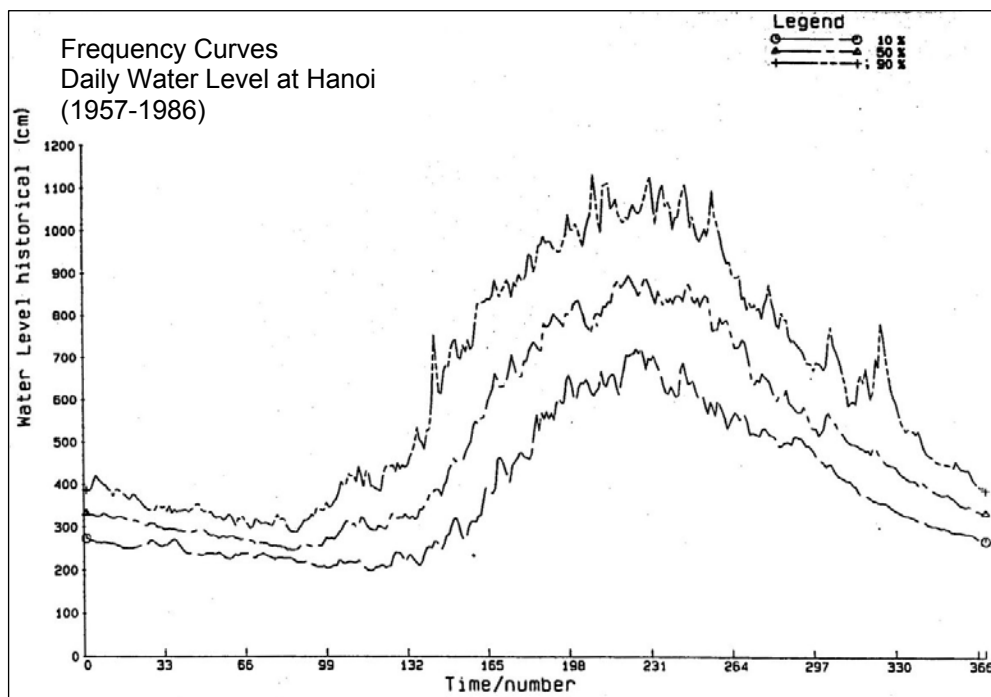
As the newer high rise buildings are usually constructed using bored piles founded in the dense gravels and cobbles of the Hanoi formation, these structures should not be significantly affected by adjacent excavation and vibration.

7) Red River Characteristics

(1) Red River Hydrology

In Hanoi, the level of the Red River is not significantly affected by the tides in the Gulf of Tonkin (where there is one tide per day: Spring 3m to 4m; Neap 1.2m to 1.8m). The Red River's high flow season lasts for five months from June to October and the low flow season lasts seven months from November to May. The annual fluctuation of water level in the Red River is usually 2mAHD to 12mAHD (14.82mAHD occurred in 1971). During the flood season, the water level of the Red River is usually 4m to 6m higher than the land surface in and around Hanoi. Frequency curves for daily water levels in the Red River (based on data from 1957 to 1986) are presented in Figure 2.1.4.

Figure 2.1.4 Average Annual Red River Water Levels



Source: Various publications

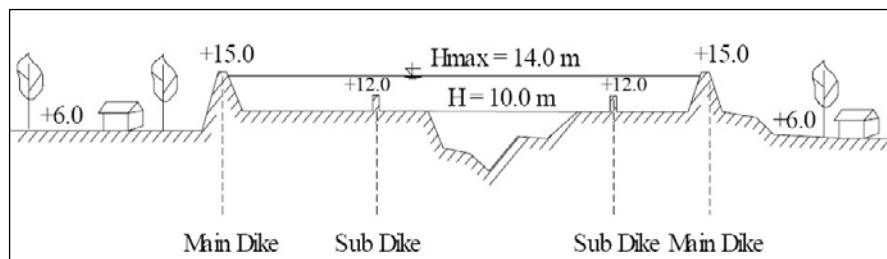
Since the dykes have been constructed six centuries ago to contain the Red River, the ground level in Hanoi is much lower than the high water levels of the Red River. A typical cross-section through the Red River showing these dykes is shown in Figure 2.1.5. The design flood water level for Hanoi is currently 13.6mAHD. However, for stability reasons it is understood it is unlikely that this design level will be raised any higher.

Thus, of all natural disasters, flooding is the one most likely to afflict the Hanoi area. The most likely months for flooding in the Hanoi area are July and August, during the annual rainy season. Minor flooding (less than 1m flood water in streets) is fairly common within the city. However, as the majority of Hanoi is at a ground level of about 6mAHD, a major flood resulting from the Red River breaking through a dyke, or from the collapse of a dam upstream of Hanoi would be devastating. The water level would be higher and the water volume and speed would be heavier than was the case in the last major flood in 1971 (when the water level reached 14.82 m AHD) because the flood channel has narrowed over the years due to silt build-up in the river. Local experts estimate water level could reach 10mAHD in certain areas of the city; actual depth in any given area would vary depending on the altitude of that area. In 1996 the flood water level at Hanoi reached

13.46mAHD.

In the event of a major flood, given enough time, Vietnamese authorities plan to destroy a portion of the protective dyke around the river well upstream from Hanoi. This would divert floodwater to less populous areas northwest of Hanoi.

Figure 2.1.5 Section Through Red River Dykes



Source: Various publications

(2) Red River Navigation

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 2. 1.4.

Table 2.1.4 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: Various sources

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 2.1.5.

Table 2.1.5 Red River Navigation Channel Requirements at Proposed UMRT Line 2 Crossing

Navigation Channel Aspects	Navigation Channel Requirements
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	0.5mAHD
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

3 PLANNING

3.1 Mass Transit Development Strategy

1) Development Strategy

In the HAIDEP Master Plan, the strategy for the development of Hanoi's public transport system has been described and outlined. The fundamental strategy for public transport in Hanoi City is to develop a coordinated and integrated system that can be composed of different transit technologies including road and rail-based systems and can be operated by different organizations under the umbrella of Public Transport Authority. Initially, the proposed urban mass transit system capacity will be provided by developing a high-capacity road-based transit in the form of a Priority Bus Transit (PBT) or a Bus Rapid Transit (BRT) system to be gradually upgraded to a high-capacity rail-based UMRT system.

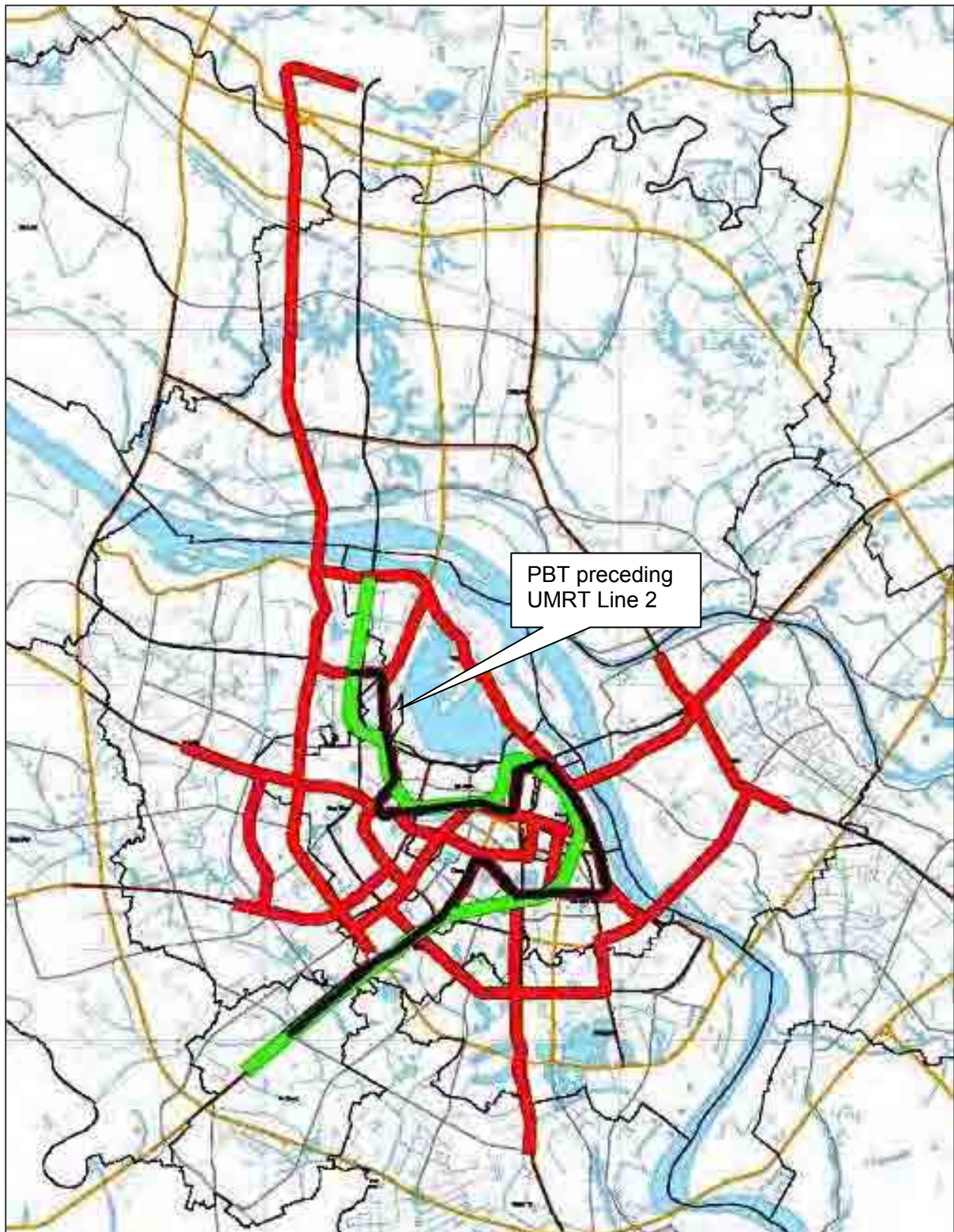
The UMRT Line 2 route is from Noi Bai in the north to Ha Dong in the South through the Hanoi City Center in order to alleviate traffic congestion in the City Center as proposed by the HAIDEP Master Plan. It is also proposed that this route could allow connection to Noi Bai International Airport—an Airport Express or a normal rail connection to the Hanoi City Center. The total length of this route will be approximately 43km. It is proposed that the whole system would be completed by 2020.

In view of the level of investment that would be required for such a system, it is proposed that the UMRT Line 2 is implemented in a phased manner to satisfy current and forecasted traffic and ridership.

Because the priority bus network can be in place years before the rail is implemented, it would be possible to introduce a priority bus transit that closely follows the planned UMRT Line 2 on existing public roads. This proposed route is shown in Figure 3.1.1 as a black line. By operating such a bus line in advance, information could become available for determining the demand along the line. Eventually, the public would become aware of this line so that the development of a high capacity UMRT line along the public transport would come as a logical development of the HAIDEP Public Transport Master Plan.

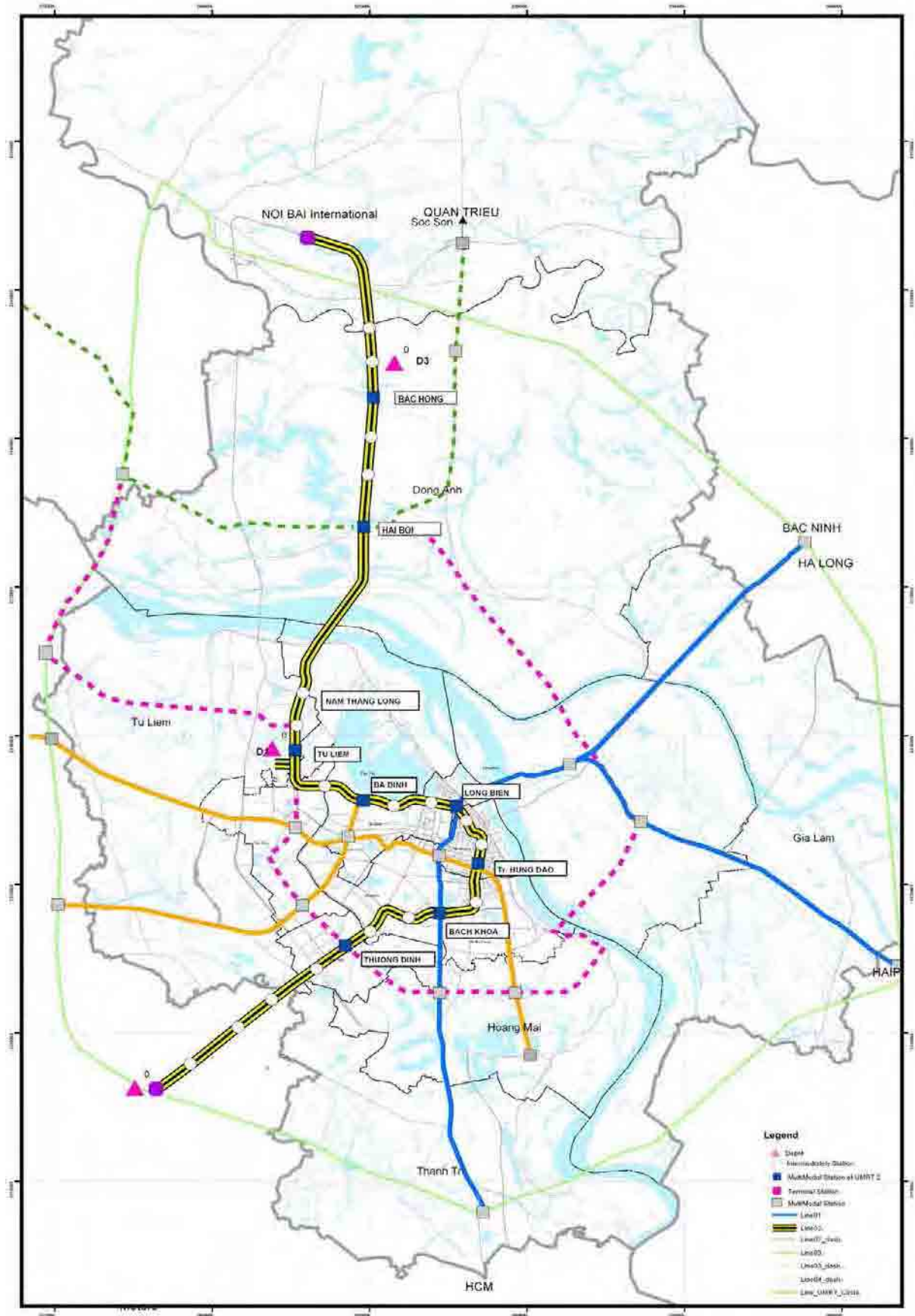
The alignment of UMRT Line 2 is subject to further study during the feasibility stage of the project; however, one option of the alignment serving the major transport corridors and integrated with good passenger transfer multimodal sites is also provided here as shown in Figure 3.1.2. As the alignment is conceived to be generally underground, UMRT Line 2 can be rerouted to serve the major intersections and multimodal transfers serving central Hanoi. The line would go west and south of West Lake, making a loop into the Hoan Kiem district and continue to the south-west towards Ha Dong.

Figure 3.1.1 Possible PBT Route Preceding the Development of UMRT Line 2



Source: HAIDEP Study Team

Figure 3.1.2 Indicative Alignment of UMRT Line 2



Source: HAIDEP Study Team

2) UMRT Line 2 Project Description and Development Phasing

The UMRT Line 2 system commences at Noi Bai international airport in the north to Ha Dong in the southwest via the central Hanoi City. The completed UMRT Line 2 system is approximately 41km and will be implemented in several phases with the full UMRT Line 2 system being completed by 2020.

The following is the likely operational phases of the UMRT Line 2 system:

- Operations Stage 1: 2013 Tu Liem to Thuong Dinh;
- Operation Stage 1A: 2013 Tu Liem to Bach Khoa (option);
- Operations Stage 2: 2016 Nam Thang Long to Ha Dong;
- Operations Stage 3: 2018 Thai Phu to Ha Dong; and
- Operations Stage 4: 2020+ Noi Bai to Ha Dong.

The phasing of is outlined in Table 3.1.1.

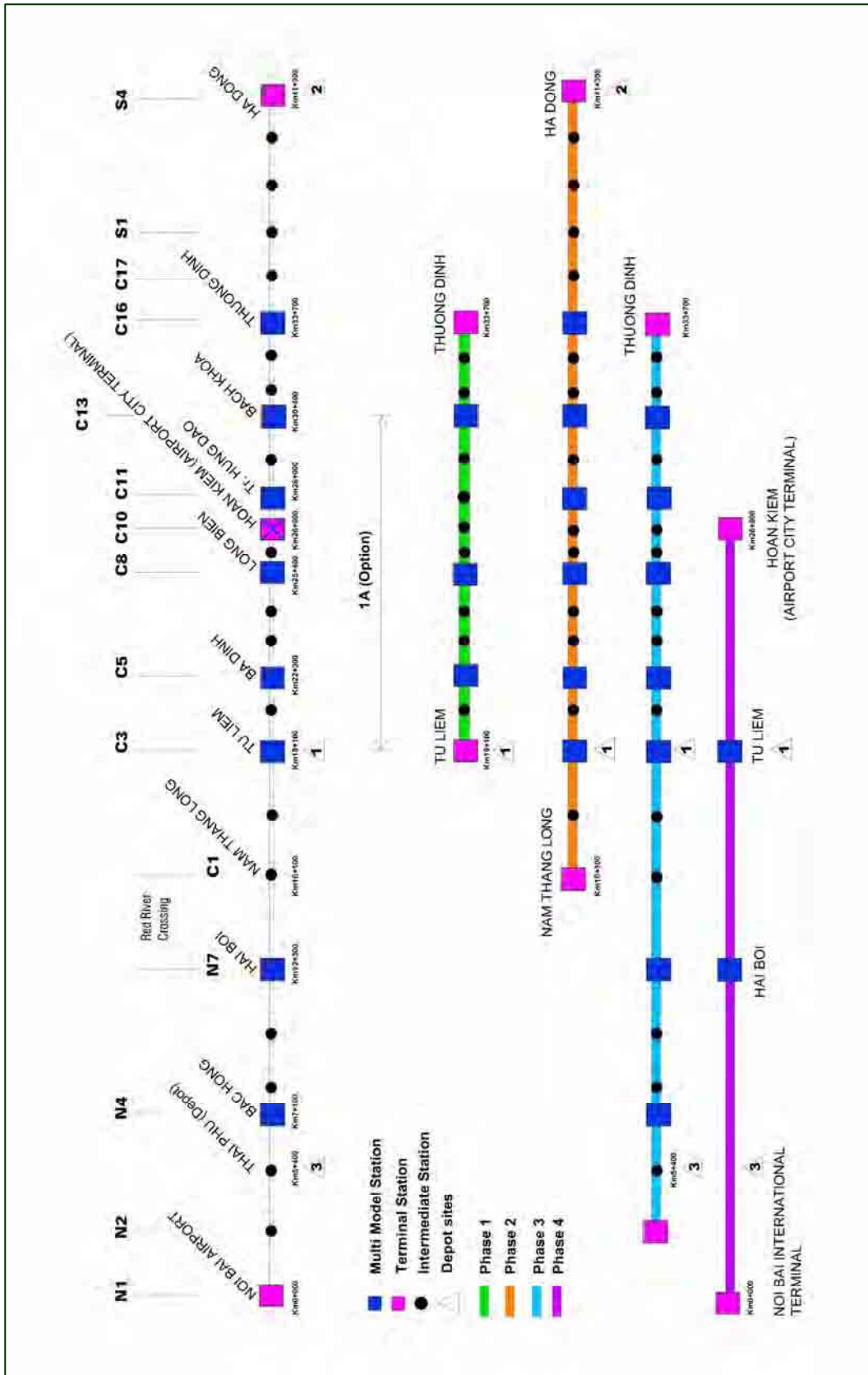
The first phase will link the northern, central and south west areas of Hanoi City and will be structured to allow for future extensions to north and south west of Hanoi city which will then make it possible to develop further the system to meet the growing population in these areas of Metro Hanoi. Meanwhile, North and south segments of the envisioned full UMRT2 system can be operated as a BRT.

Table 3.1.1 UMRT Line 2 Development Phasing

Stage	Segment	Length (km)	No. of Stations	Start of Operation
1	Tu Liem to Thuong Dinh	15.2	14	2013
1A	Tu Liem to Bach Khoa	11.5	11	2013
2	South Thang Long to Tu Liem Thuong Dinh to Ha Dong	10.2	7	2016
3	South Thang Long to Thai Phu	10.7	5	2018
4	Thai Phu to Noi Bai	5.4	2	2020+
Total	Ha Dong to Noi Bai	41.5	28	

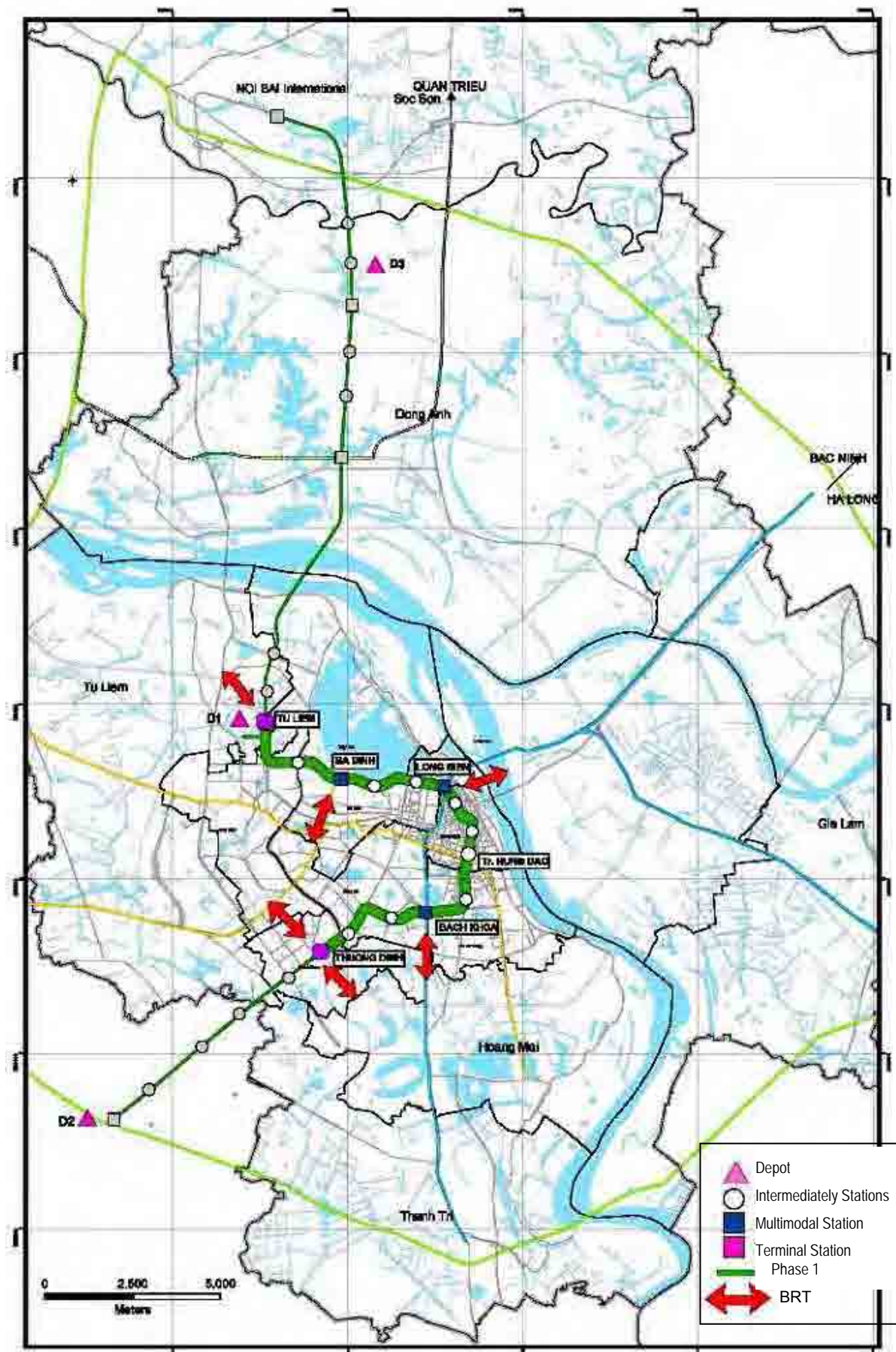
Source: HAIDEP Study Team

Figure 3.1.3 UMRT Development Plan



Source: HAIDEP Study Team

Figure 3.1.4 UMRT Line 2 Stage 1-Initial System (2013)



Source: HAIDEP Study Team

3.2 Features of Vertical Alignment

The following vertical route alignment options have been identified by the study team:

- (i) Option A: All Underground;
- (ii) Option B: Elevated/at grade;
- (iii) Option C: Elevated/Underground; and
- (iv) Option D: Elevated/At grade/underground.

From the initial assessment and depending on the alignment constraints, a combination of these vertical alignment options will be required along the route from Noi Bai International to Ha Dong.

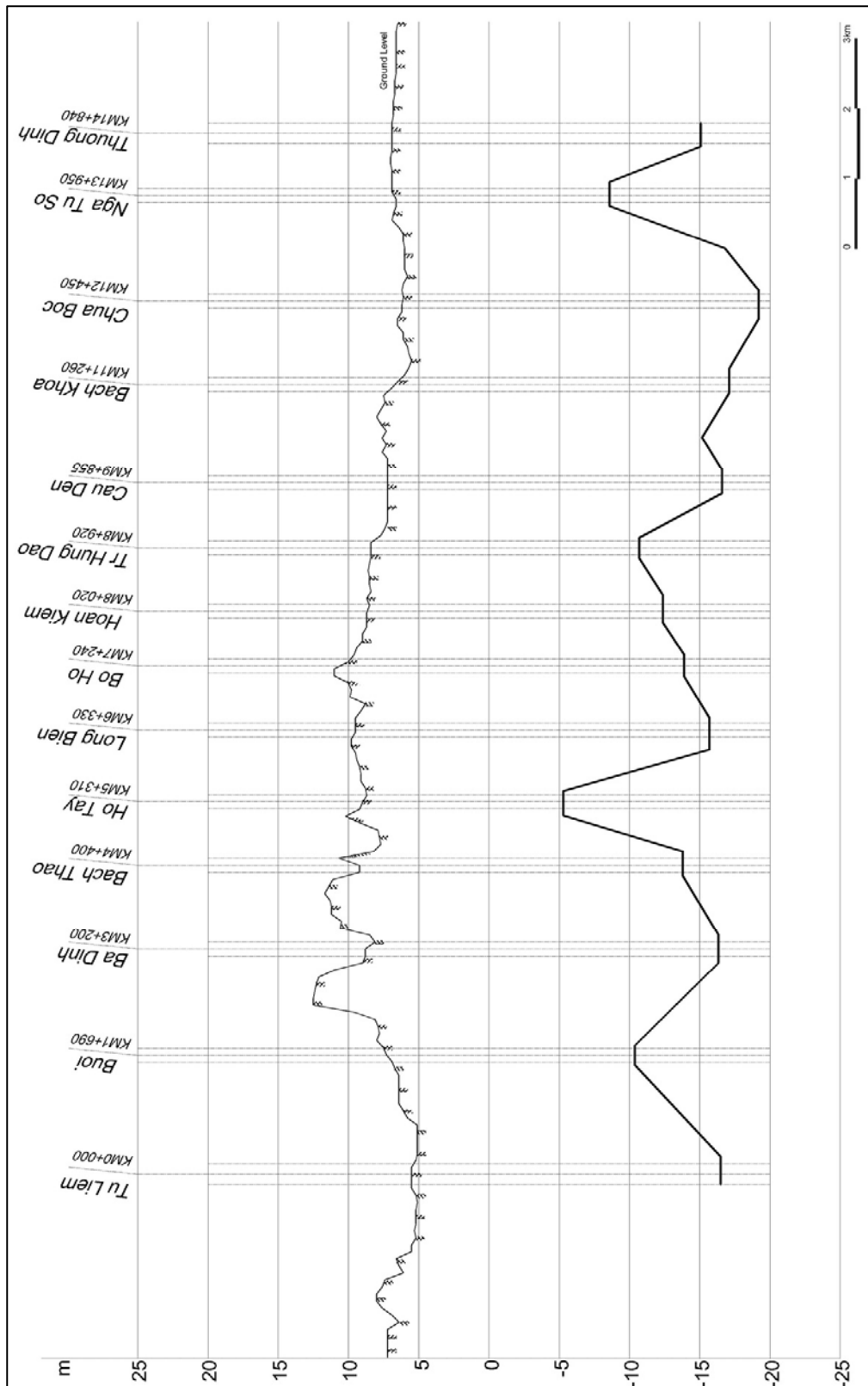
In view of the physical constraints such as congested streets, buildings and surface infrastructure, the Initial System through Hanoi City Center is proposed to be an underground metro system.

North and south section of the Initial System through the City Center, the Line 2 may continue as an underground, at grade, elevated system or any combination thereof. Each of the systems has its advantages and disadvantages (social, environmental, financial, constructability, etc.) which will need to be evaluated in the later stage when these extensions are more fully assessed.

A brief summary of the vertical alignment along the UMRT Line 2 route is as follows:

- (i) Noi Bai International to Thai Phu-Underground below the proposed second runway;
- (ii) Thai Phu to Hai Boi-at grade/elevated/underground depending on land use;
- (iii) Hai Boi to Nam Thang Long (Red River Crossing): elevated and underground crossing;
- (iv) Nam Thang Long to Tu Liem: elevated or underground depending on environmental and commercial development;
- (v) Tu Liem to Thanh Xuan: Underground within Ring Road 2.5, and
- (vi) Thanh Xuan to Ha Dong: At grade or elevated depending on environmental and highway crossing.

Figure 3.2.1 Vertical Alignment of Initial System



Source: HAIDEP Study Team

The study team has determined the likely location of the tunnel portal. The final location will depend on future land use and other technical factors to be studied in the next phase of the study.

3.3 Horizontal Alignment Alternatives for the Initial System

1) General

It is proposed that the Hanoi City section be implemented as an initial system to be completed by 2013. This initial system will be approximately 15km long commencing south of the Hong River and terminating at Thuong Dinh.

The route shall, as much as possible, be determined by existing and planned city infrastructure and in particular roadways. This will minimize the potential effect on existing buildings and surface infrastructure and will also minimize the extent of surface disruption during the construction period.

In assessing various alternatives, limited information has been available to determine existing foundation types and conditions, particularly in regard to shallow and deep level foundations, geotechnical conditions, etc. Therefore it will be necessary to assess such issues in a detailed manner in the next stage of study.

2) Design Criteria

For the design of the alignment, the following general criteria have been adopted:

- (i) Stations shall be generally located at about 1.0km intervals to accommodate a catchment radius of 500m around each station
- (ii) The UMRT Line 2 line should be not less than 1.0km within any other adjacent or parallel UMRT systems for the reason noted above.
- (iii) Minimize the number of buildings which require demolition to accommodate construction of the tunnels and stations
- (iv) Minimize the extent to which relocations (dwellings, commercial, etc) shall be required.
- (v) Minimize the extent of potential damage to existing buildings and infrastructure.
- (vi) To facilitate the latter above criteria it is proposed the route alignment shall be kept within public space such as main roads, parks, etc and that the tunnel is kept a minimum of 1.0 times the tunnel diameter below ground level to the crown/roof of the tunnel.
- (vii) The route alignment shall take into account proposed development plans in terms of future transport systems (roads, BRT, etc), residential, commercial and mixed use integrated developments to avoid potential impact with such developments.
- (viii) Station locations in some instances shall need to facilitate connections to other planned UMRT systems and therefore will be fixed.
- (ix) The location and design of the maintenance depot and stabling of trains shall be optimized to avoid unnecessary capital expenditure and/or redundant facilities for the Initial System and subsequent extensions leading to the completion of the system.

The following design criteria have been adopted in considering the horizontal alignment:

- (i) Horizontal radius curves (80km/hr attainable line speed): 300m (minimum)
- (ii) Minimum radius through stations: straight
- (iii) Absolute minimum radius through stations: 2000m (intermediate/commuter station)
- (iv) Minimum radius in Depot connecting lines: 300m
- (v) Minimum radius in Depot: 140m

(vi) Length of circular arc between transitions: 50m (minimum), 25m (absolute minimum)

(vii) Distance between adjacent running tracks: 4.0m (minimum c/c)

The following design criteria have been adopted in considering the vertical alignment:

(i) Running Lines and Depot connecting lines gradient: 3% (maximum), Level (minimum)

(ii) Gradient through station platforms: level

(iii) Gradient in tunnels: 0.3% (minimum)

(iv) Gradient of Depot fans: 1% (maximum), Level (minimum)

(v) Gradient of stabling sidings at stations and in Depot: 0.3% (maximum), Level (minimum)

(vi) Length of gradient between vertical curves: 50m

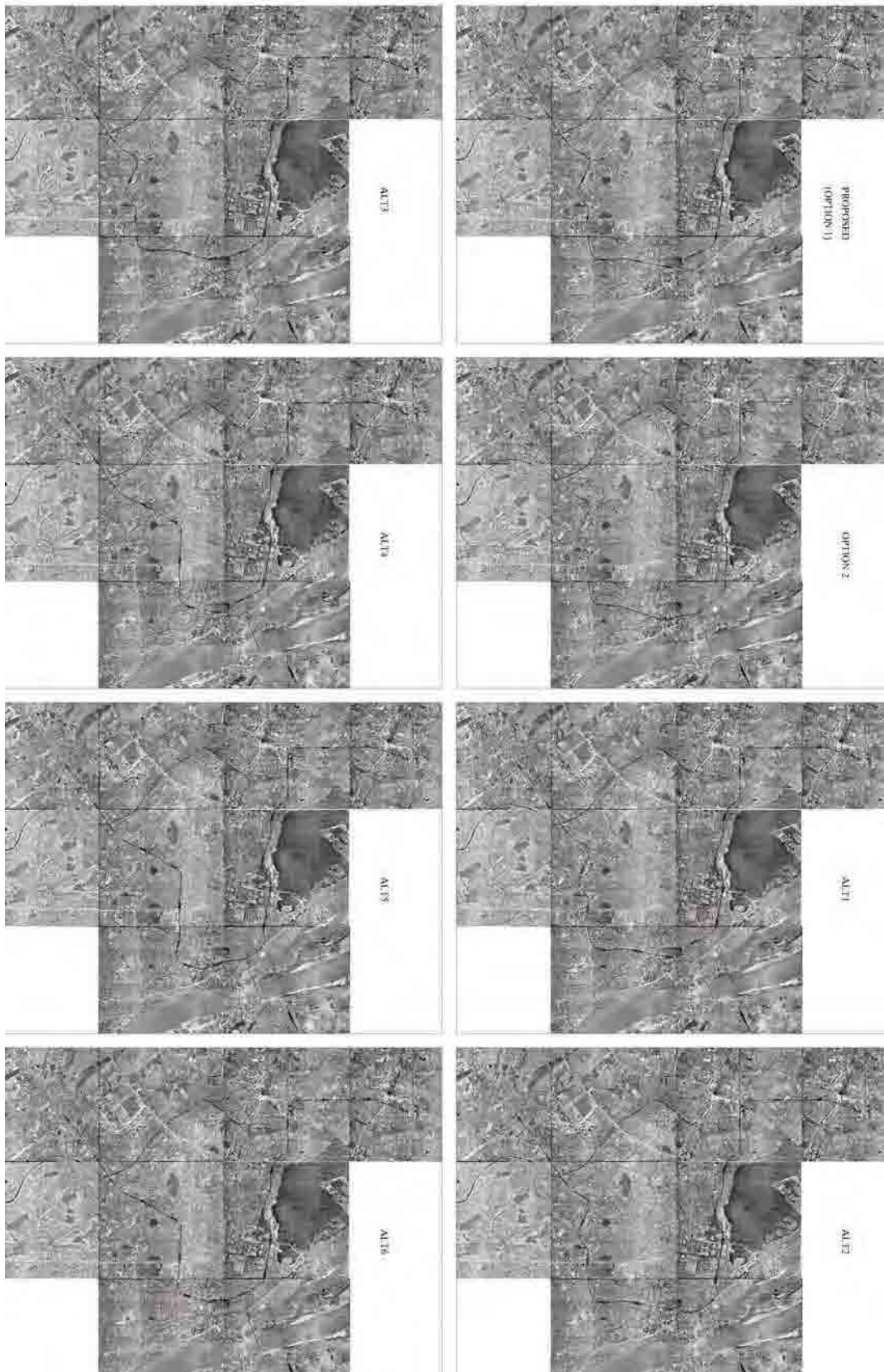
(vii) Vertical curves radius: 3000m (minimum)

(viii) Vertical curves in Depot lines and sidings: 1500m (minimum)

3) Route Investigation

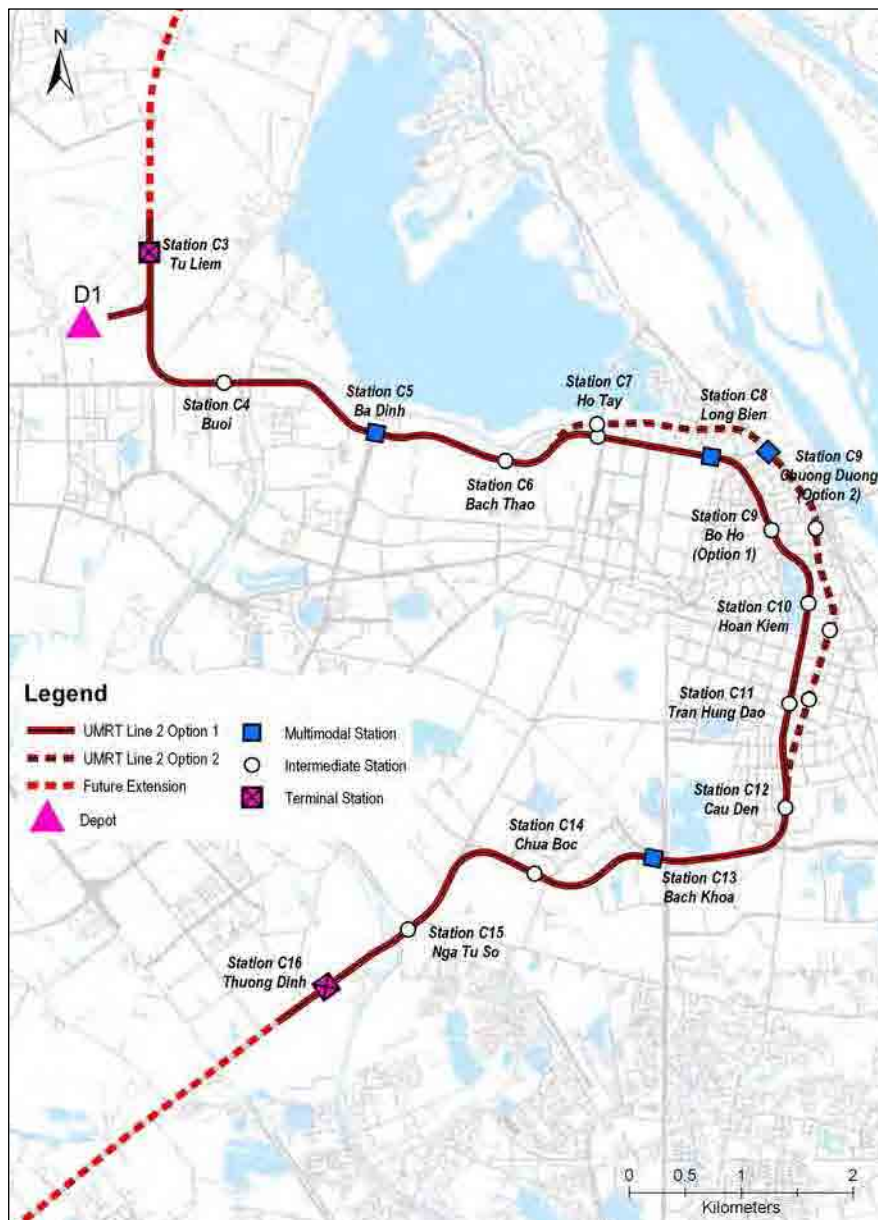
Based on the criteria outlined above, a number of alternative routes for the UMRT Line 2 system in particular the initial system have been considered. From preliminary assessment of alternative routes through the city center two preferred alignments have been identified for further consideration and examination:

Figure 3.3.1 Candidate Horizontal Options for UMRT Line 2 Initial System



Source: HAIDEP Study Team

Figure 3.3.2 Preferred Alignment Options for Initial System



Source: HAIDEP Study Team

4) Preferred Alignment Option 1

(1) General Alignment

The main depot and workshop will be located at Tu Liem and connected by an approach track from the cut and cover underground section of tunnel track to grade. The depot and workshop would be at grade with landfill.

This route starts from Tu Liem Station C3 and extends south to Hoang Quoc Viet Street at Nghia Tan.

The route would then turn east via Hoang Quoc Viet Street and cross Bui Street (Ring Road) and travel east along Hoang Hoa Tham and Phan Dinh Phung until Xuan Thanh Street.

At Xuan Thanh Street the alignment would turn south along Hang Giay, Dong Xuan, Hang

Duong, Hang Ngang, Hang Dao and then turns south-east to Dinh Tien Hoang Street.

Thereafter the route would extend south along Hang Bai, Pho Hue until Dai Co Viet Street and turn west along Dai Co Viet, cross the Vietnam Railway line (UMRT Line 1) and travel along Dao Duy Anh and Chua Boc Street until Tay Son Street.

The alignment would then turn south-west at Pho Tay Son and Nguyen Trai Street and travel south to Thuong Dinh Station, Station C16, which would form the most southerly terminal station for the UMRT Line 2 Initial System.

(2) Stations

Station C3: Tu Liem Station on the extension of Nguyen Van Huyen Street, underground station with two line and island type platforms. The alignment will extend on a downward gradient through cut and cover construction and through the portal interface between tunnel boring machine and cut and cover construction techniques.

Station C4: Buoï Station, west side of Buoï Street, under Hoang Quoc Viet Street, underground station with two line and one island type platform.

Station C5: Ba Dinh Station, cross point of Van Cao and Hoang Hoa Tham Street, underground station with two line and one island type platform forming interchange with UMRT Line 3b.

Station C6: Bach Thao Station, Ngoc Ha area, underground station with two line and one island type platform.

Station C7: Ho Tay Station, Thuy Khue area, cross point of Phan Dinh Phung and Hung Vuong Street, underground station with two line and one island type platform.

Station C8: Long Bien Station, east end of Phan Dinh Phung Street, underground station with two line and one island type platform forming interchange and multimodal station with UMRT Line 1 and bus transport systems.

Station C9: Bo Ho Station, under Hang Ngang and Hang Dao Street, underground station with two line and one island type platform.

Station C10: Hoan Kiem Station, Dinh Tien Hoang Street adjoining Trang Tien Street, underground station with two line and 3 side type platforms. A pocket track with turnouts at each end of the station shall be constructed.

Station C11: Hung Dao Station, cross point of Hang Bai and Tran Hung Dao Street, underground station with two line and one island type platform. In the future, UMRT Line 3 will be extended to the east and this station will be the connection station of both lines.

Station C12: Cau Den Station southern end of Hue Street, underground station with two line and one island type platform.

Station C13: Bach Khoa Station, cross point of Dai Co Viet Street and Vietnam Railway line (UMRT Line 1), underground station with two line and one island type platform. This station will be connection station with UMRT Line 3.

Station C14: Chua Boc Station, east end of Chua Boc Street, underground station with two line and one island type platform.

Station C15: Nga Tu So Station, cross point of Tay Son and Truong Chinh Street, underground station with two line and one island type platform. The constructed

underpass of road will be connected to the station structure directly. South of this station will be the portal between the tunnel boring machine and cut and cover construction techniques.

Station C16: Thuong Dinh Station, cross point of Nguyen Trai and Vu Trong Phung Street, underground station with two line and one island type platforms. This station will be constructed using cut and cover techniques. The alignment will have an upward gradient within cut and cover construction to extend to elevated alignment. The station will have three lines and 2 island-type platforms. Turnouts will be constructed at the south end of the station.

(3) Structure and Construction Methods

- (i) Stations C3 and C16 are partially below ground with platforms below ground and concourses at ground level. Portal sections between cut and cover construction and tunnel boring machine techniques are located south of Station C3 and north of Station C16.
- (ii) From Station C4 to Station C15 construction will be underground structure.
- (iii) Underground station is 2 or 3 floors box type underground structure. The number of floors will depend upon the depth of the tunnels and physical constraints imposed on the station structure. The lowest floor is for track and platform and upper floor is for concourse and station utilities.
- (iv) A third intermediate floor may be used passenger circulation and for rail systems and/or station facilities/equipment/plant rooms.
- (v) Where surplus space to rail and station operation is available such space could be used for public use such as parking, pedestrian road or commercial tenancies.
- (vi) The main depot and workshop will be at Tu Liem and connected by an approach track from the cut and cover underground section of tunnel track to grade. The depot and workshop is at grade with landfill.
- (vii) The underground section between Station C3 and Station C16 will twin tunnel single track construction. For the TBM section it is proposed that Earth Pressure Balance and/or Slurry TBM is used to minimize the relocation of buildings and to minimize potential deformation of the buildings by settlement or distortion of ground level caused by the underground earth works.

(4) Advantages

- (i) The general alignment passes through the Hanoi New Town Development Project area such as Phu Thuong Ciputra, Khu Doan Ngoai Giao and KDTM.
- (ii) Station C13 is the connection point between UMRT Line 2 and UMRT Line 1 (Vietnam Railway line).
- (iii) Station C11 will be the junction between UMRT Line 2 and UMRT Line 3.
- (iv) Dinh Tien Hoang, Hang Bai, Pho Hue and Dai Co Viet Streets are sufficiently wide to facilitate construction of the underground stations and tunnels without land acquisition.

(5) Disadvantages

- (i) Almost all the buildings along the streets between Station C8 and Station C10 will be subject to potential impact from tunnel and station construction. In addition, it is likely that building and surface infrastructure within the immediate vicinity of the construction

along this route will also suffer potential damage because of the anticipated extent of surface construction equipment required and construction traffic, haulage routes, etc.

- (ii) It is likely that many significant mature and historic trees would require removal which would affect the local fauna and flora and potential destruction to sensitive habitats.
- (iii) In addition, many buildings/land may require compensation for underground passage of the tunnel route.
- (iv) The alignment is along the secondary dyke to the Ho Tay Lake.

5) Preferred Alignment Option 2

(1) General Alignment

This alignment is identical to Option 1 with the exception of the section between Bach Thao (Station C6) and Cau Den Station (Station C12). Therefore this section of the report only describes the differences in alignment between these two stations.

This route starts from Station C3 at Tu Liem extending south to Hoang Quoc Viet Street at Nghia Tan.

The route would then turn east via Hoang Quoc Viet Street and cross Bui Street (ring road 2nd) and travel east along Hoang Hoa Tham and Quan Thanh Streets to Long Bien.

At Long Bien the alignment would turn south along Tran Nhat Duat, Nguyen Huu Huan, Ly Thai To, Ngo Quyen to Le Van Huu Street.

Thereafter the route would extend south to Hue until Dai Co Viet.

At Dai Co Viet the route would turn west along Dai Co Viet, cross the Vietnam Railway line (UMRT Line 1) and travel along Dao Duy Anh and Chua Boc Street until Tay Son Street and turn south at Pho Tay Son and Nguyen Trai Street to the Thuong Dinh Station (Station 17).

(2) Stations

This section only describes those stations between Bach Thao (Station C6) and Cau Den Station (Station C12) where the alignment is different to Option 1.

Station C6: Bach Thao Station, Ngoc Ha area, underground station with two line and one island type platform.

Station C7: Ho Tay Station, Thuy Khue area, cross point of Quan Thanh and Hung Vuong Street, underground station with two line and one island type platform.

Station C8: Long Bien Station-at north end of Tran Nhat Duat Street, underground station with two line and one island type platform forming interchange and multimodal station with UMRT Line 1 and bus transport systems.

Station C9: Chuong Duong Station, under Nguyen Huu Huan near the intersection with Tran Nhat Duat, underground station with two line and one island type platform.

Station C10: Hoan Kiem Station, inter-section of Ly Thai To, Ngo Quyen and Le Lai, underground station with two line and 3 side type platforms with a pocket track and turnouts at each end of the station.

Station C11: Hung Dao Station, at south end of Ngo Quyen Street, underground station with two line and one island type platform. In future, UMRT Line 3 will be extended to the east and this station will be the connection station of both lines

Station C12: Cau Den Station, southern end of Hue Street, underground station with two line and one island type platform.

(3) Structure and Construction Methods

- (i) As per preferred alignment Option 1, Station C3 and Station C16 are partially below ground with platforms below ground and concourses at ground level. Portal sections between cut and cover construction and tunnel boring machine techniques are located south of Station C3 and north of Station C16.
- (ii) From Station C4 to Station C15 construction will be underground structure.
- (iii) Underground station is 2 or 3 floors box type underground structure. The number of floors will depend upon the depth of the tunnels and physical constraints imposed on the station structure. The lowest floor is for track and platform and upper floor is for concourse and station utilities.
- (iv) A third intermediate floor may be used as passenger circulation and for rail systems and/or station facilities/equipment/plant rooms.
- (v) Where surplus space to rail and station operation is available such space could be used for public use such as parking, pedestrian road or commercial tenancies.
- (vi) The main depot and workshop will be located at Tu Liem and connected by an approach track from the cut and cover underground section of tunnel track to grade. The depot and workshop would be at grade with landfill.
- (vii) The underground section between Station C3 and Station C16 will twin tunnel single track construction. For the TBM section, it is proposed that Earth Pressure Balance and/or Slurry TBM is used to minimize the relocation of buildings and to minimize potential deformation of the buildings by settlement or distortion of ground level caused by the underground earth works.

(4) Advantages

- (i) The general alignment passes through the Hanoi New Town Development Project area such as Phu Thuong Ciputra, Khu Doan Ngoai Giao and KDTM.
- (ii) Station C13 is the connection point between UMRT Line 2 and UMRT Line 1 (Vietnam Railway line).
- (iii) Station C11 will be the junction between UMRT Line 2 and UMRT Line 3.
- (iv) Nguyen Huu Huan, Ngo Quyen Streets are reasonably wide to facilitate construction of the underground stations and tunnels without excessive land acquisition.
- (v) The location of the Station C8 at Long Bien allows for an effective multimodal station to link with the Long Bien Bridge bus terminal.
- (vi) The Alignment avoids sensitive areas with significant historic trees and minimize the disruption of public park spaces and therefore avoid destruction of any sensitive flora and fauna habitats.
- (vii) Station C10 is located near Hoan Kien Lake and the People's Committee building, both significant public areas of importance.
- (viii) The alignment avoids having land compensation issues and minimizes the impact on any heritage buildings and surface infrastructure.

(5) Disadvantages

- (i) The alignment is along the secondary dyke to the Ho Tay lake.

- (ii) Long Bien Station (station C8) and the tunnel along Tran Nhat Duat Street will be constructed near the dyke to the Hong River.
- (iii) In addition, many buildings/land may require compensation for underground passage of the tunnel route.

6) Preferred Alignment Options Summary and Comparison

The advantages and disadvantages of each option are described below:

Table 3.3.1 Advantages and Disadvantages of Each Option

Option	Advantages	Disadvantages
Option 1	Bach Khoa Station (station C13) connects to UMRT Line 1	Alignment route is along road of secondary dyke to Ho Tay Lake.
	Hung Dao Station (station C11) connects to UMRT Line 3	Alignment passes through narrow streets and high density buildings between Long Bien (station 8) and Bo Ho (station 9) requiring demolition and reconstruction of existing buildings within the ancient quarter
	Dinh Tien Hoang, Hang Bai, Pho Hue, and Dai Co Viet Streets are sufficiently wide to minimize impact on buildings for construction of tunnels and stations	Alignment passes under a number of areas of buildings which may require compensation for underground works
	Alignment and station passes through and near the center of the ancient quarter	The alignment along Hoan Kiem Lake is likely to require removal of many mature and historic trees and result in destruction to any sensitive fauna and flora habitats
	Alignment follows main forecast patronage nodes	The alignment along Hoan Kiem Lake could encounter construction problems due to the proximity of the lake
		There is no station at the center of the ancient quarter although the stations are within 500m of the center of the ancient quarter.
		Alignment through the ancient quarter and building areas will cause restriction on any future development because of the tunnel restriction zone
Option 2	Bach Khoa Station (station C13) connects to UMRT Line 1	Alignment route is along road of secondary dyke to Ho Tay Lake.
	Hung Dao Station (station C11) connects to UMRT Line 3	Alignment route is near and along the primary dyke to the Hong River for a length of approximately 800m
	Nguyen Huu Huan, Ly Thai To are reasonably wide to minimize impact on buildings for construction of tunnels and stations	Alignment passes under a number of areas of buildings which may require compensation for underground works
	Alignment and station passes near the ancient quarter	There is no station at the center of the ancient quarter although the stations are within 500m of the center of the ancient quarter.
	Alignment follows main forecast patronage nodes	
	Hoan Kiem Station (Station C10) is located near the Peoples Committee building, Hoan Kiem Lake and the Opera House	
	The alignment minimizes any potential damage and/or destruction to any significant or historical trees adjacent to Hoan Kiem Lake.	

Source: HAIDEP Study Team

3.4 Maintenance Depots and Stabling

1) General

An essential element of the operations of a modern rail network is a strategic location of the depot workshop and vehicle stabling or storage areas for the system.

The depot site should be located as close as possible to the mainline track and at a point which will allow phased development of the transit system.

It is considered that because of the 41km length of the UMRT Line 2, it will be necessary to provide at least one main maintenance and workshop depot and stabling for UMRT Line 2 while a number of satellite maintenance depots with stabling will be located along the UMRT Line 2 alignment.

A number of alternatives have been considered for the location of maintenance and workshop depot as described below.

(1) Alternative Workshop Site 1

- (a) **Location:** Ha Dong: Adjacent to Ha Dong Station.
- (b) **Advantage:** Convenient for transportation of rolling stocks, via existing railway.
- (c) **Disadvantage:** This site is located along an already planned LRT system proposed by China, thus, this site would not be suitable for implementation of the UMRT Line 2 Initial System.
- (d) **Remark:** This site is not recommended since it would not be suitable for UMRT Line 2 Initial System.

(2) Alternative Workshop Site 2

- (a) **Location:** Phu Dien: Adjacent to Phu Dien Station.
- (b) **Advantage:** Convenient for transportation of rolling stocks, via existing railway.
- (c) **Disadvantage:** An additional approach track from the UMRT Line 2 planned alignment would be necessary and the location is within the vicinity of the planned French LRT.
- (d) **Remark:** This location is considered unsuitable for the workshop because it disrupts the UMRT Line 3 system.

(3) Alternative Workshop Site 3

- (a) **Location:** Nghia Tan: Adjacent to west side of proposed UMRT Line 2 alignment and north side of Duong Hoang Quoc Viet
- (b) **Advantage:** Adjacent to proposed UMRT Line 2 station requiring only a short approach track from the main line to the depot.
- (c) **Disadvantages:** The area available for the workshop and depot is only 5ha which is considered to be very limiting. When the UMRT Line 2 Initial System is extended to the north and south, from Noi Bai airport to Ha Dong respectively, the area required for the workshop and depot is likely to be between 5 - 15ha. Should this site be used as the main depot and workshop for UMRT Line 2 Initial System it would be necessary to develop another maintenance workshop elsewhere in the future when the complete UMRT Line 2 is developed. Since it is preferable to have all workshop facilities

located in one location for operational efficiency, a workshop located at Site 3 could only be considered temporary and therefore all workshop facilities in this location would ultimately become redundant resulting in redundant early capital expenditure for the UMRT Line 2 Initial System. However, the site could be converted to provide a satellite maintenance depot and stabling in the future. Site 3 location is also included in the development plan for the extension of Nguyen Van Huyen road. The road extension would be required to deviate around the site and in addition the site would traverse across and terminate a number of main east-west roads. Furthermore, the elevated track to the north will disrupt the east-west main road traffic at a level crossing and/or limit the height clearance of the road at the elevated track in the proposed diplomatic development zone.

- (d) **Remark:** In view of the above, this location for the main maintenance depot and workshop is not recommended.

(4) Alternative Workshop Site 4

- (a) **Location:** Tu Liem: South of Xuan Dinh Street and north of Hoang Quoc Viet Road
- (b) **Advantage:** It is adjacent to UMRT Line 2 Initial System station and immediately south of an approved Korean development. The available site is greater than that required for the depot and workshop (10-15ha). The site requires only about 1km approach track from the main UMRT Line 2 track. Since it is adjacent to an approved development it would be possible to extend the development over the depot. This would be a most cost effective and operationally efficient location accommodating both the Initial System and the completed system of the UMRT Line 2 system.
- (c) **Disadvantage:** Ground conditions will require some ground improvement works and possibly some landfill to minimize flooding. The site is adjacent to a proposed development.
- (d) **Remark:** This would be a recommended site for the location of the main maintenance depot and workshops

(5) Alternative Workshop Site 5

- (a) **Location:** Xuan Dinh: North side of Xuan Dinh Street.
- (b) **Advantage:** The site width is adequate and approximately 15ha is available for the depot development which is adequate to accommodate the completed UMRT Line 2. There are no approved proposed development plans in this location.
- (c) **Disadvantage:** The site is currently a wetland and extensive ground improvement works and landfill will be necessary. Resulting impact on fauna (migratory birds, butterflies, frogs, etc) and flora may be undesirable. It will also be necessary to develop UMRT Line 2 Initial System to Nam Thanh Long which has limited patronage/ridership in the early years of operation and therefore limited revenue and return on investment for this section of railway north of Tu Liem. In addition an additional approach track of about 1.5km will be necessary to the depot
- (d) **Remark:** While this location is generally suitable for the initial and completed system the ground conditions, the detrimental environmental impact and the need to extend the Initial System to Nam Thanh Long resulting in increased capital expenditure for the could exclude this location for further consideration.

(6) Alternative Workshop Site 6

- (a) **Location:** Dong Ngoc Ciputra: North side of Ciptra Development area and south side of the Hong River dyke.
- (b) **Advantage:** Easy access from north end of UMRT Line 2 Initial System.
- (c) **Disadvantage:** Additional approach track of about 2km is necessary from Nam Thanh Long in addition to an extension from Tu Liem, the termination point for Initial System. Also, part of this area is designated for a planned sewage plant for the Ciptra Development.
- (d) **Remark:** This location is not recommendable for workshop.

(7) Alternative Workshop Site 7

- (a) **Location:** North of the Hong River and west of the future extension of the UMRT Line 2 alignment.
- (b) **Advantage:** An excess of 15ha of land is available which is sufficient area for depot and workshop. Only a short access is required to the depot and workshop from main UMRT Line 2 alignment in the future.
- (c) **Disadvantage:** A long temporary access track and river crossing (either high level bridge or tunnel under the river) of the Hong River would be necessary in the UMRT Line 2 Initial System.
- (d) **Remark:** This location is not recommended for depot and workshop for UMRT Line 2 Initial System. However, in future when the UMRT Line 2 Initial System is extended to Noi Bai Airport, this location would be effective as a satellite depot and stabling yard.

2) Summary and Recommendations

- (i) The required area required for the main maintenance depot and workshops, including stabling, will be of the order of 10-15ha for the complete UMRT Line 2 system with a number of satellite depots for maintenance and stabling.
- (ii) For the UMRT Line 2 Initial System the full maintenance and workshop area will be required while it will be possible to reduce the extent of stabling provided. Therefore the total area required for the UMRT Line 2 Initial System will be less than the complete system.
- (iii) The locations at Site 1 and 2 are not available and are considered not suitable for the location of the maintenance depot and workshop for the Initial System.
- (iv) Workshop Sites 3, 4, 5, 6 & 7 are suitable for construction of the main depot and workshops.
- (v) Workshop Site 7 is not considered suitable for construction of the main depot and workshops to accommodate the UMRT Initial System.
- (vi) Workshop Sites 3, 4, & 5 could be developed for the Initial System.
- (vii) The Workshop Site 3 has planned development and would be unable to ultimately accommodate the main depot and workshops for the complete system. This location is considered unsuitable.
- (viii) The Workshop Site 6 also has planned development and would initially require extension of the Initial system and ultimately relocation to another site incurring

additional capital cost. This location is therefore considered unsuitable.

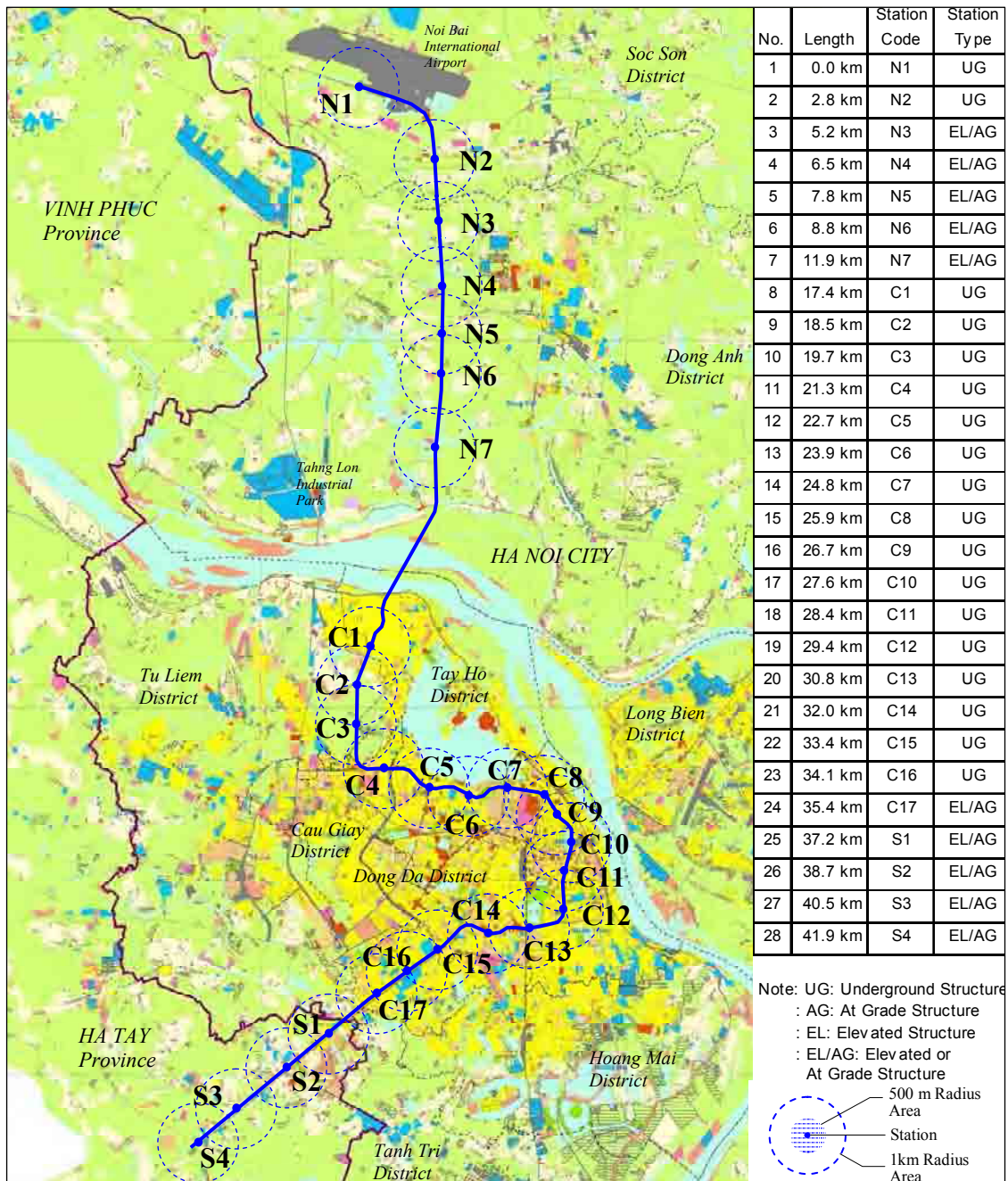
- (ix) Workshop Site 5, while being suitable for the main depot would require the UMRT Line 2 Initial System to terminate at Xuan Dinh which provides for little patronage for the increased capital expenditure. Also, the ground conditions and environmental impact would incur additional costs. This location is not recommended.
- (x) Workshop Site 4 at Tu Liem is recommended as the most suitable location for the main depot and workshops to accommodate both the UMRT Line 2 Initial System and the complete system from Noi Bai to Ha Dong.

3.5 Existing Conditions and Urban Development Context in Station Areas

1) Stations and its Catchment Area

In this section, the study for the station area development takes the case of the option 1 route alignment of UMRT Line 2 with regard to existing conditions, issues and development directions. The UMRT Line 2 has 28 proposed stations in the route which reaches 41km. Every station needs to be carefully planned in terms of desirable function and role of transportation and urban development considering different levels of urbanization and socio-economic conditions.

Figure 3.5.1 Existing Conditions and Location of UMRT Line 2 and its Stations

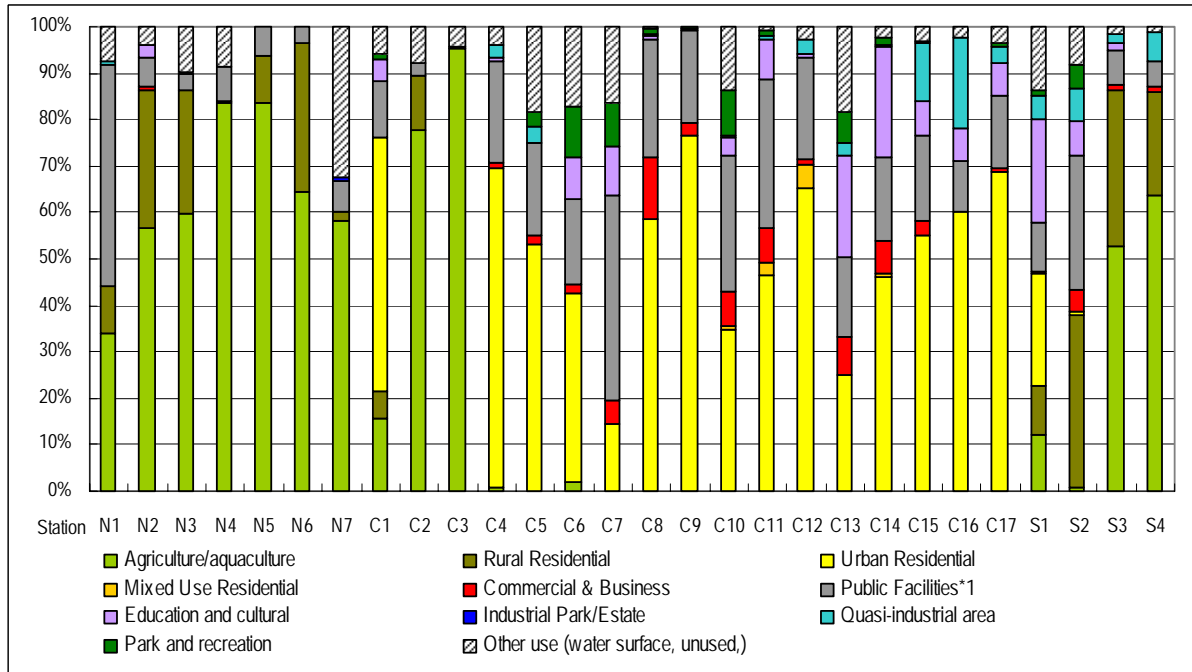


Source: HAIDEP Study Team

2) Existing Land Use of Station Catchment Area

Existing land use of each station area covering area within 500m radius characterizes stations. Figure 3.5.2 shows clearly the difference between existing urban area where stations from C1 to C17 are located and rural areas for stations with predominant agricultural land from N1 to C3 and S1 to S4. On the other hand, public facilities including government, security, health and welfare, etc., and education-cultural facilities of distinct land use in the vicinity of the station. This suggests that UMRT Line 2 can contribute greatly to ease commuting public from the residence to the work place.

Figure 3.5.2 Existing Land Use of Station Area (500m radius range)



Source: HAIDEP Study Team

3) Current Urbanization and Environment along UMRT Line 2

The route of UMRT Line 2 has various features in terms of level of urbanization such as the city center to rural agricultural field. The route can be divided into three blocks with each having distinct environmental character as follows.

(a) Dong Anh North Block

This block stretching about 12 km from the terminal in the Noi Bai International Airport to the southern area before crossing the Red River is located in Dong Anh District as the rural district where paddy fields and villages are spreading out. Dong Anh city center along NH3 as the district center which serves local communities and northern industrial area will be involved as one of catchment areas of UMRT Line 2. On the other hand, Thang Long Industrial Park as one of the successful FDI industrial zone has led economic development in the city. Surroundings of the Thang Long Industrial Park are promoted into other urban development such as infrastructure and housing development.

This area is expected to become a new urban growth area of the city where urban development and settlement needs to be supported by the UMRT Line 2 as a key public transportation measure for this area to link with the city center and the international airport.

(b) Ho Tay West Block

This block from the station C1 to C3 is located in suburban area of the west side of the West Lake, where paddy fields and villages still remain and large housing real estate development (CIPUTRA) is under construction. The Government is promoting the “New Administration Center” including commercial, business, government and institutions such as embassies in this block.

UMRT will play a key role in providing public transportation service for this new urban center of Hanoi in conjunction with adequate new urban development taking account of transit-oriented urban development formulation.

(c) Ho Tay South Block

This block from the station C4 to C7 is located in the urban center area in the south side of the West Lake, where residential areas are predominant with some commercial and business offices and institutions. The water frontage of the West Lake is one of potential areas for tourism and recreation development where some restaurants and hotels are operated.

UMRT will play a key role in providing public access service to this waterfront recreation and tourism area of Hanoi.

(d) Hanoi CBD Block

This block from the station C8 to C12 covers major areas of the central business district (CBD) of Hanoi, where government offices, institutions, commercial and business areas are predominant including the historical center of Thang Long citadel, Ancient Quarter and French Quarter. The water frontage of the West Lake is one of potential areas for tourism and recreation development and some restaurants and hotels are operated.

UMRT will play an essential role in providing public access service to this CBD area of Hanoi to contribute to formulation of attractive urban center with pedestrian friendly walking environment while access by other modes such as motorcycle and car will be replaced by UMRT. On the other hand, urban redevelopment and renewal are expected also to promote station areas maximizing high potential of property development in this block.

(e) Dong Da South Block

This block from the station C13 to C15 covers major residential area of Hanoi as a part of Dong Da district, where large collective housing areas are predominant with some commercial and business offices and institutions.

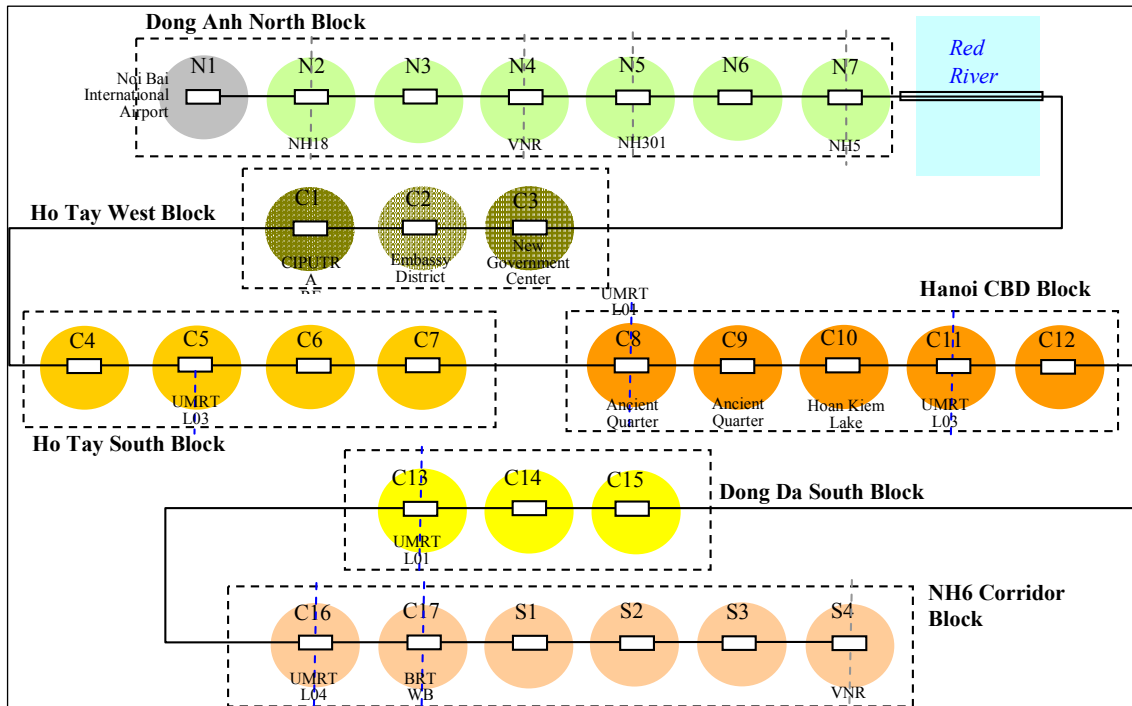
(f) NH6 Corridor Block

This block from the station 16 to S4 covers a part of the NH6 urban corridor of Hanoi City and Ha Tay province, where collective housing areas and large SOE factories are distributed along the corridor of the HN6. Apart from Hanoi city, the administrative center as provincial capital of Ha Tay province is located in this corridor with some commercial and business offices and governmental institutions. The urban area in Ha Tay province is not matured yet with narrow depth of urban area from NH6 road.

Major patronages from the housing areas of the Dong Da South Block and the NH6 Corridor Block are expected to use UMRT for their commuting to work places or

schools. Commercial and business activities will be encouraged and promoted by station area development to serve local communities in this block, while old housing and residential areas in poor living condition are also expected to be revitalized and improved on this occasion of UMRT development.

Figure 3.5.3 Aggregated UMRT Line 2 Stations and its Urban Block



Source: HAIDEP Study Team

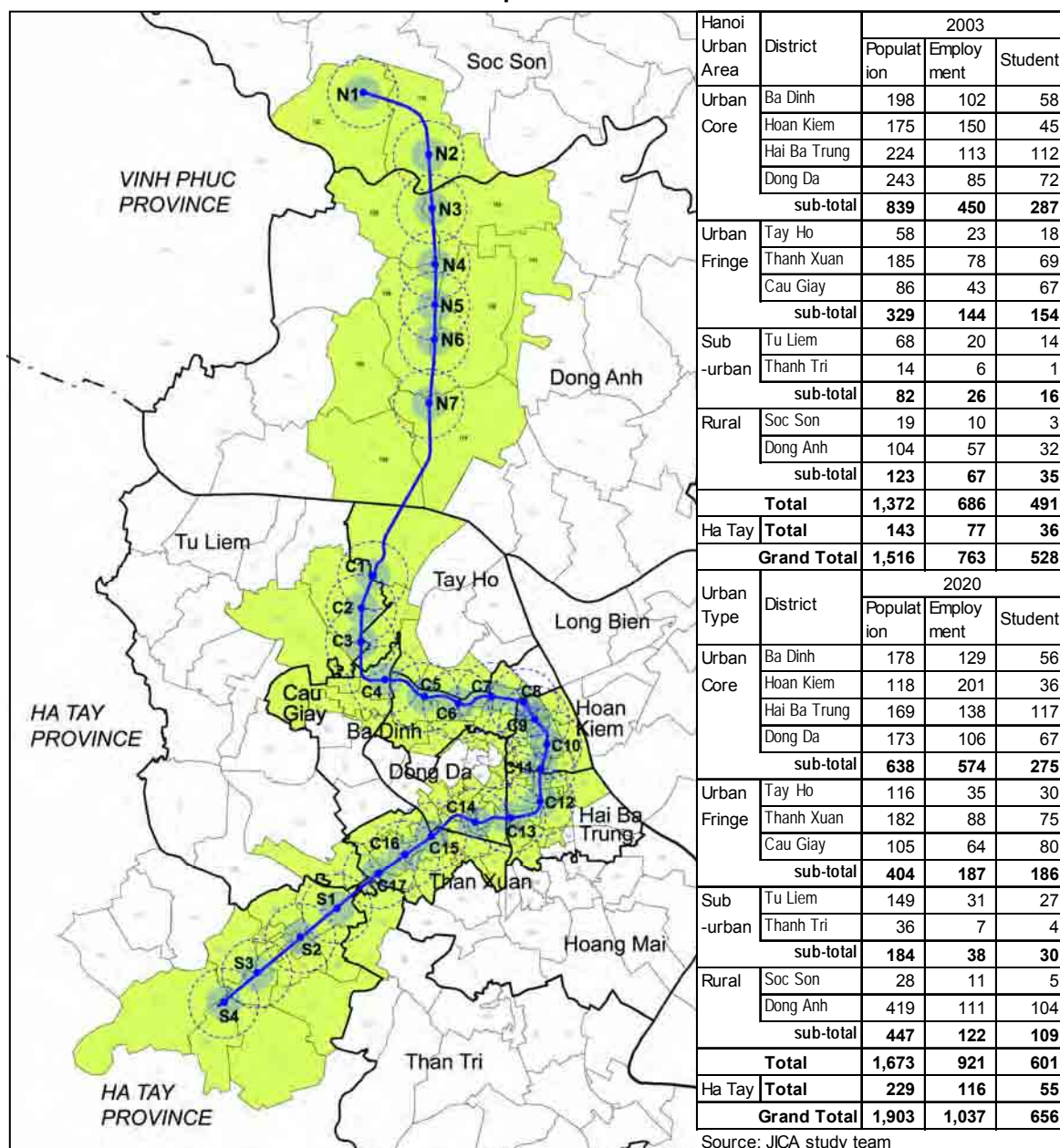
4) Socio-economic Framework for Station Area Development

As characterized in the previous section, station areas at present have various urban conditions depending upon the status of urbanization. The area expected to be affected by the stations development presumably at present (2003) involves about 1,516,000 residents while employment in the same area is expected to be 763,000 workers and 528,000 students. The HAIDEP Master Plan gives the future framework to the station development catchment area, which will have a 1,903,000 population by 2020.

Notably, population in the Dong Anh North block is expected to increase 3.6 times from the existing population (447,000) as one of the most rapidly increased residential areas in the affected areas, which is composed of 122,000 workers and 601,000 students in the area.

Population in urban fringe, sub-urban and Ha Dong in Ha Tay province areas also indicate another potential growth area in 2020, rather than Urban Core with modest population distribution. Tay Ho district with the new government center development and Tu Liem and Ha Dong area will increase population rapidly by 1.6 to 2.0 times. UMRT will play an important role in serving residents in those areas to commute to the urban center.

Figure 3.5.4 Socio-economic Conditions and Framework for Station Development Catchment Areas



Source: HAIDEP Study Team

5) Current Development Trend along Proposed UMRT Line 2

There are several plans and projects in the vicinity area along the UMRT Line 2 including ongoing transport and urban development projects and related plans. Figure 3.5.5 and Table 3.5.1 indicates an overview of these plans and projects. Considerable projects are briefly explained in the following sections.

(1) Road and Transport Plans and Projects

The central government and Hanoi City authority has prepared and implemented several projects of road and transport development in Hanoi including significant project some of which will affect UMRT Line 2 technically. The following are considerable projects to be depended directly or indirectly on the UMRT Line 2 are presented in order of project status.

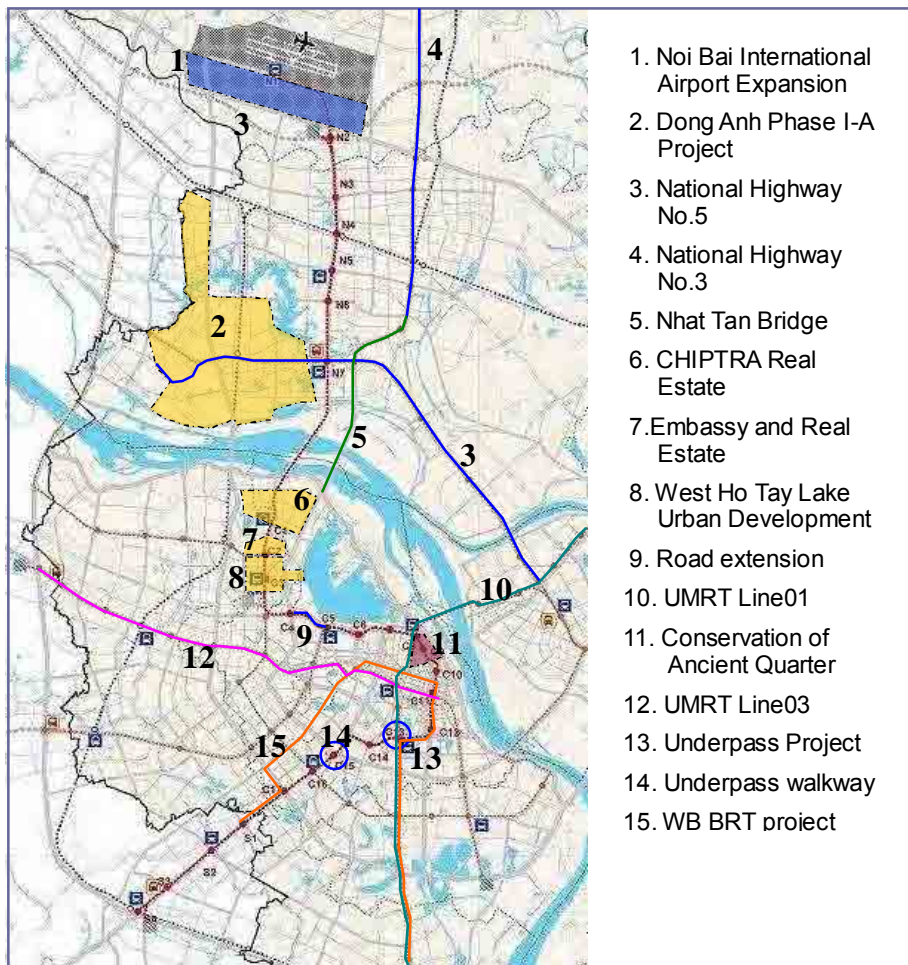
- (i) Nhat Tang Bridge and Access Road (linking with NH3) Construction (financed by JBIC) in conjunction with UMRT alignment;
- (ii) Underpass Construction in the intersection between Dai Co Viet and Le Duan Street (financed by JBIC) at Station No.13;
- (iii) UMRT Line 1 (VNR Line) and its stations for transfer (Line2 – station C8 / C13);
- (iv) UMRT Line 3 (French Line) and its station for transfer (Line2 – station C11); and
- (v) BRT project (WB) for transfer.

(2) Urban Development Plans and Projects

Several urban development projects in Hanoi some of which will affect the condition of UMRT Line 2 technically have been approved by the Central government and Hanoi City authority. Considerable projects to be depended directly or indirectly for UMRT Line 2 in order of project status are shown in below.

- (i) CIPUTRA housing complex development project (on-going) where UMRT Line 2 and station C2 development is proposed to pass through this urban area;
- (ii) New Embassy complex development project where UMRT Line 2 and station C3 development is proposed to pass through this urban area; and
- (iii) West Ho Tay Urban Development (New Administrative Center) project (implemented by Korean Consortium) where UMRT Line 2 and station C2 development is proposed to pass through this urban area.

Figure 3.5.5 Current Plans and Project Along UMRT Line 2



Source: HAIDEP Study Team

Table 3.5.1 Current Plans and Projects in Station Vicinity and Affected Area

Current Ongoing Projects and Plans	Location	Status	Type and Contents of Project		Related UMRT Station
			Urban Sector	Road & Transport Sector	
1. Noi Bai International Airport Expansion	Soc Son District	Long-term Plan	Resettlement program regarding to Airport expansion	Airstrip and terminal expansion after 2020	N1 station
2. Dong Anh Phase I-A Project	Dong Anh District (Kim No commune)	On-going	Van Tri Marsh Country Golf Club Development	Access road and community road improvement	--
	Dong Anh District (Hai Boi, Vung La communes)	Approved Plan	Thang Long North Industrial Park Development	Access road and community road improvement	--
	Dong Anh District (Kim Chung commune)	Approved Plan	Thang Long North Bridge Real Estate Development	Local road development	--
	Dong Anh District (Hai Boi commune)	Approved Plan	--	Cargo Distribution Center Development	--
3. National Highway No.5	Dong Anh District	On-going	--	Existing NH5 extension from Long Bien to Dong Anh area	N6 Station
4. National Highway No.3	Dong Anh District	On-going	--	Existing road widening and changing alignment	--
5. Nhat Tan Bridge	Tay Ho and Dong Anh District	On-going	--	Bridge construction and access road development linking with NH3	--
6. CIPUPTRA Real Estate	Tay Ho District	On-going	Housing development including golf course and commercial facilities	Local road development	Station C1
7. Embassy and Real Estate	Tay Ho District	Approved Plan	Housing development including embassy and commercial business facilities	Local road development	Station C2
8. West Ho Tay Lake Urban Development	Tay Ho and Tu Liem District	Approved Plan	New Government Center (Public, commercial business facilities and residential area)	Local road development	Station C3
9. Road extension	Cau Giay District	Approved Plan	--	Existing road widening and changing alignment	Station C4
10. UMRT Line 1	Hoang Kiem and Hai Ba Trung District	Approved Plan	--	Elevated line project with elevated station development	Station C8 /13
11. Conservation of Ancient Quarter	Hoang May District	Long-term Plan	Historical town and structure conservation and renovation	Local road and traffic management	Station C8/ 9
12. UMRT Line 3	Hai Ba Trung District	Approved Plan	--	Subway line project with underground station development	Station C11
13. Underpass Project	Hai Ba Trung / Dong Da District	On-going	--	Underpass project in the intersection of Dai Co Viet road	Station C13
14. Underpass walkway	Dong Da District	On-going	--	Underpass project in the Tay Son road	Station No.15
15. BRT project	Than Xuan District	On-going	--	Bus Rapid Transit project financed by World Bank	Station C13

Source: HAIDEP Study Team

6) Key Station Development Concept

(1) Station N7: Van Tri Lake New Town Urban Center

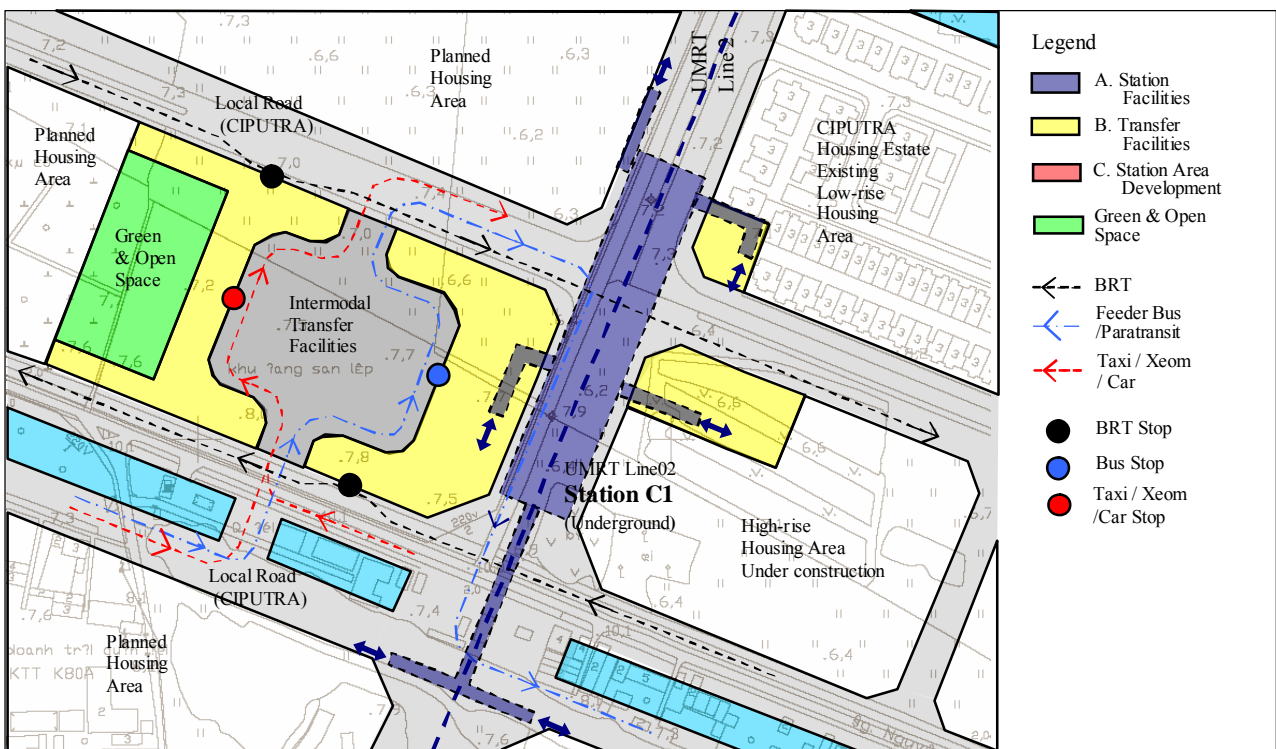
The proposed station N7 located in the middle of the proposed new urban center in the Dong Anh district with larger patronage in 2020 will play a pivotal role in formulating the

new urban center with public transport system serving residents and visitors not only to visit this center but also to link with the Hanoi city center. This station will also play as the “Transportation Hub” in connection with BRT (Line 2) system and proposed inter-city bus terminal where regional and public traffic transport will connect.

(2) Station C1: CIPUTRA Housing Estate Area

The proposed station C1 located in the southern middle part of the new housing area (CIPUTRA) with second largest patronages in 2020 will play a key role in serving residents mainly in the CIPUTRA housing estate to commute from/to the city center. This station will also function as the terminal for the temporal BRT system between C1 to the northern Hanoi area beyond the Red River in short-medium term phase of UMRT Line 2 development in order to transfer to the BRT as part of substitution UMRT Line 2.

Figure 3.5.6 Development Image for C1 Station and its Station Area

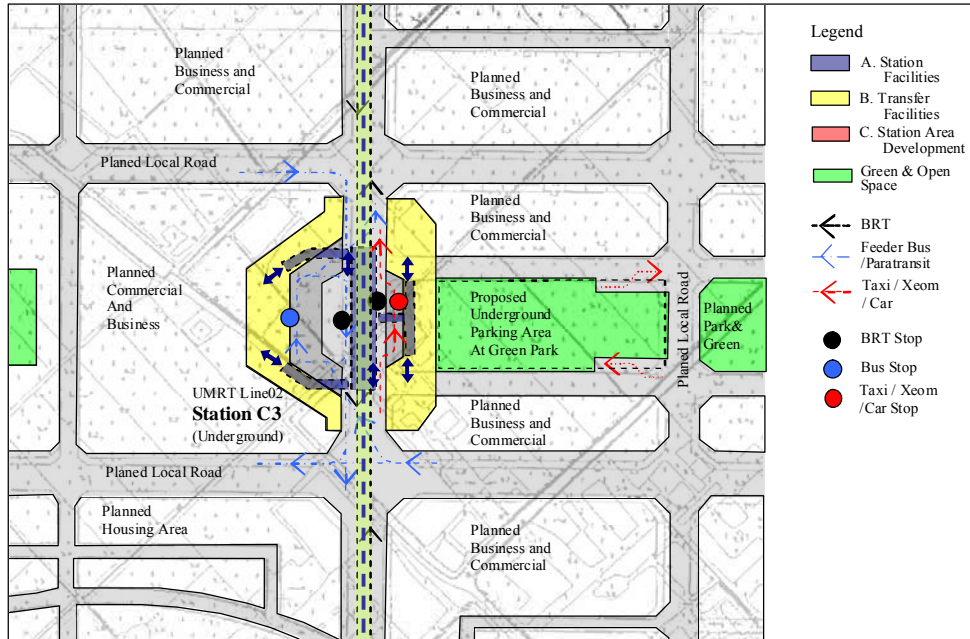


Source: HAIDEP Study Team

(3) Station C3: New Government Center Development Area

The proposed station C3 located in the middle of the planned new government center (NGC) with larger patronages and BRT Line 4 in 2020 will play an important role in serving businesses and shoppers to visit from other places. This station will also link with the station for BRT of UMRT 4. The NGC of Hanoi is expected to become one of the attractive urban centers in Hanoi offering convenient transportation service (e.g. shuttle bus) and other advanced infrastructure befitting the new government center.

Figure 3.5.7 Development Image for C3 Station and its Station Area

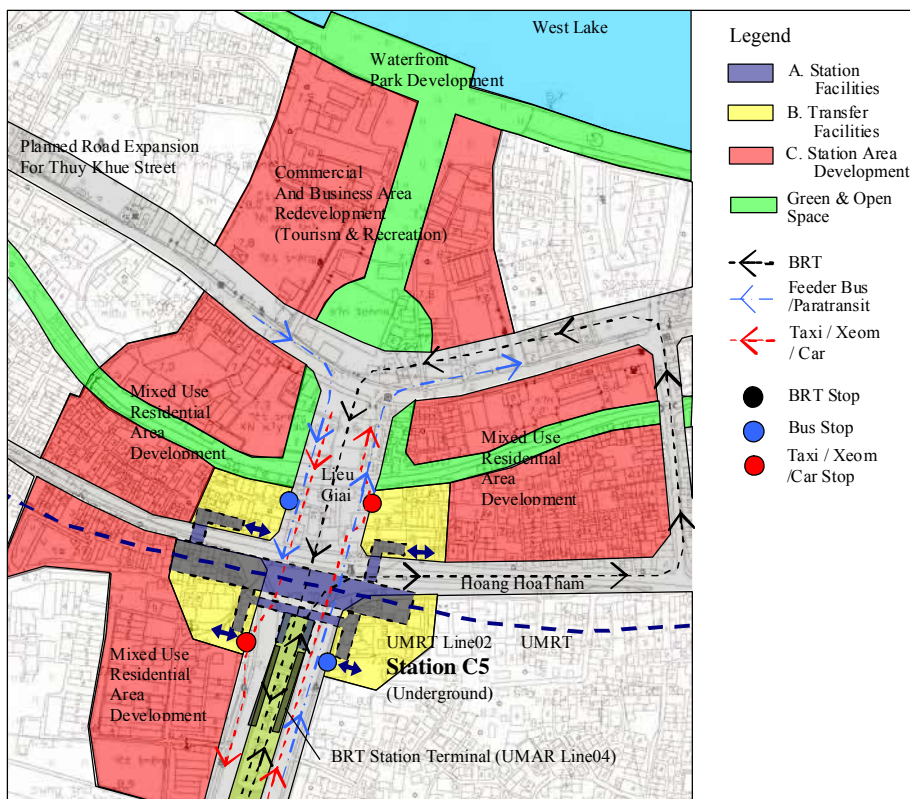


Source: HAIDEP Study Team

(4) Station C5: West Lake Lakeside Development Area

The proposed station C5 located in the waterfront area with the terminal station of BRT Line 3 in 2020 is expected to promote urban redevelopment in the vicinity area of the station. The station area is expected to become one of the focus areas with potential urban redevelopment including attractive tourism and recreational development in front of the West Lake.

Figure 3.5.8 Development Image for C5 Station and its Station Area

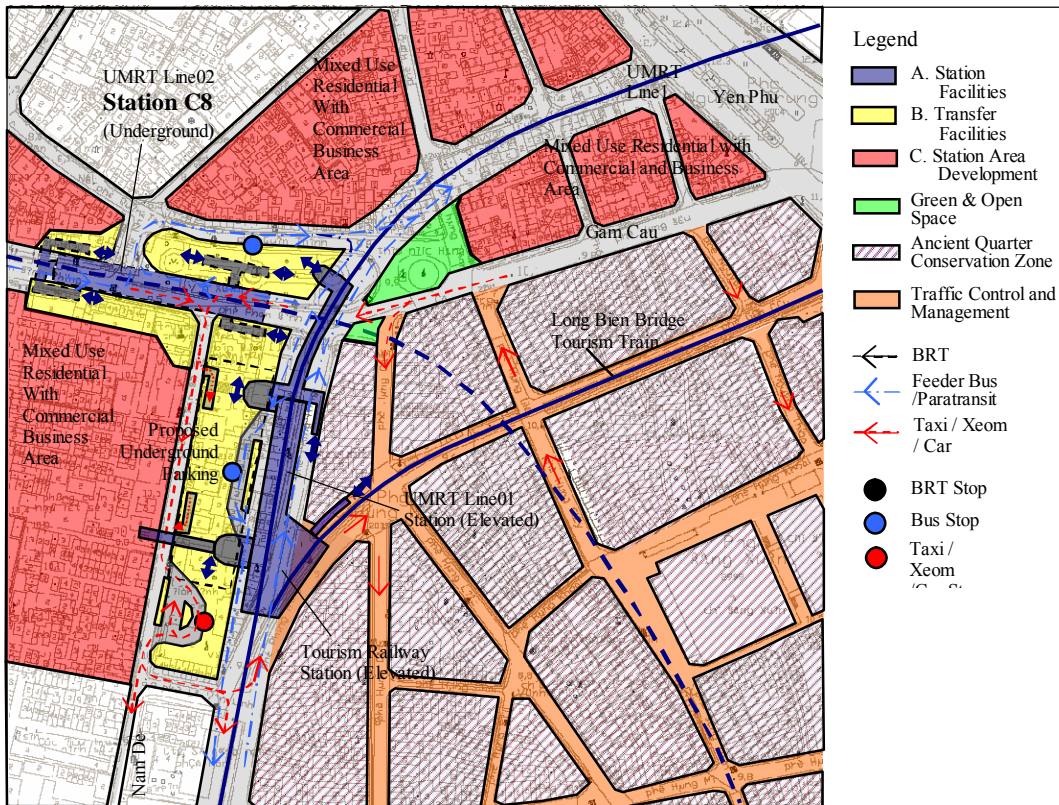


Source: HAIDEP Study Team

(5) Station C8: Hoan Kiem Transportation Hub

The proposed station C8 is located at northern marginal side of the Ancient Quarter (AQ) where both stations of UMRT Line 1 and proposed tourism railway for the Long Bien Bridge form the transportation hub. The station area is expected to promote urban redevelopment in conjunction with UMRT Line 1 (with proposed arterial road development) and Line 2 development, taking account of harmonized development with AQ in terms of landscape and urban design.

Figure 3.5.9 Development Image for C8 Station and its Station Area

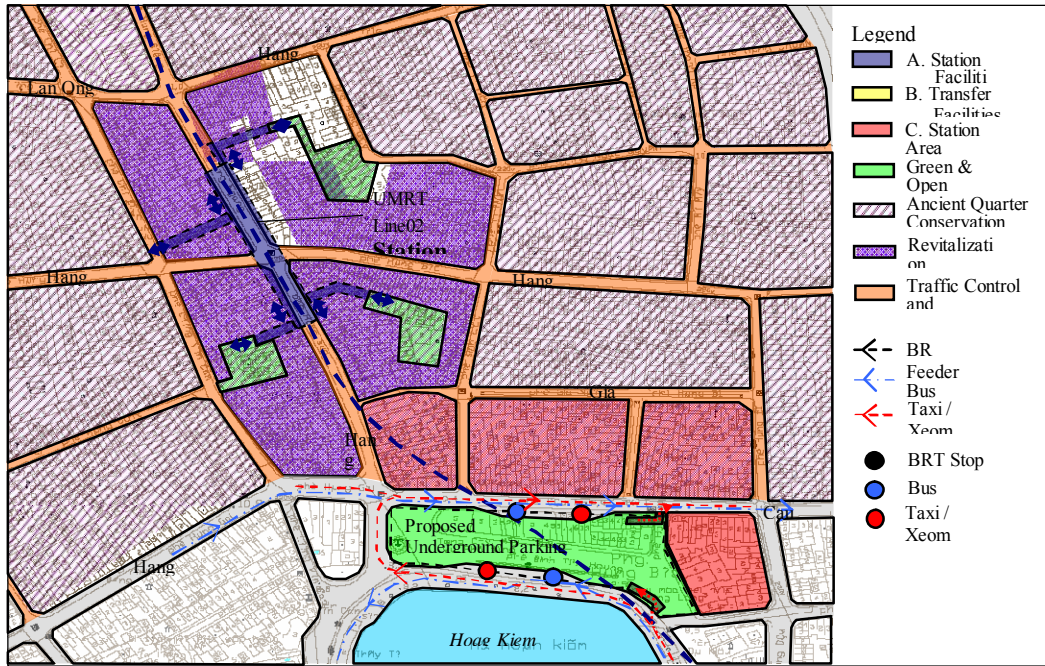


Source: HAIDEP Study Team

(6) Station C9: Ancient Quarter Gateway

The proposed station C9 is located in the middle of the Ancient Quarter Conservation area (AQC) where culture and history through the presence of historical buildings and urban structure have been retained. The station area is expected to promote urban redevelopment in conjunction with UMRT Line 2 station development. This contributes to comfortable street environment through pedestrian-friendly road composition and attractive commercial and business streets improvement, taking account of well-organized landscape and urban design.

Figure 3.5.10 Development Image for C9 Station and its Station Area

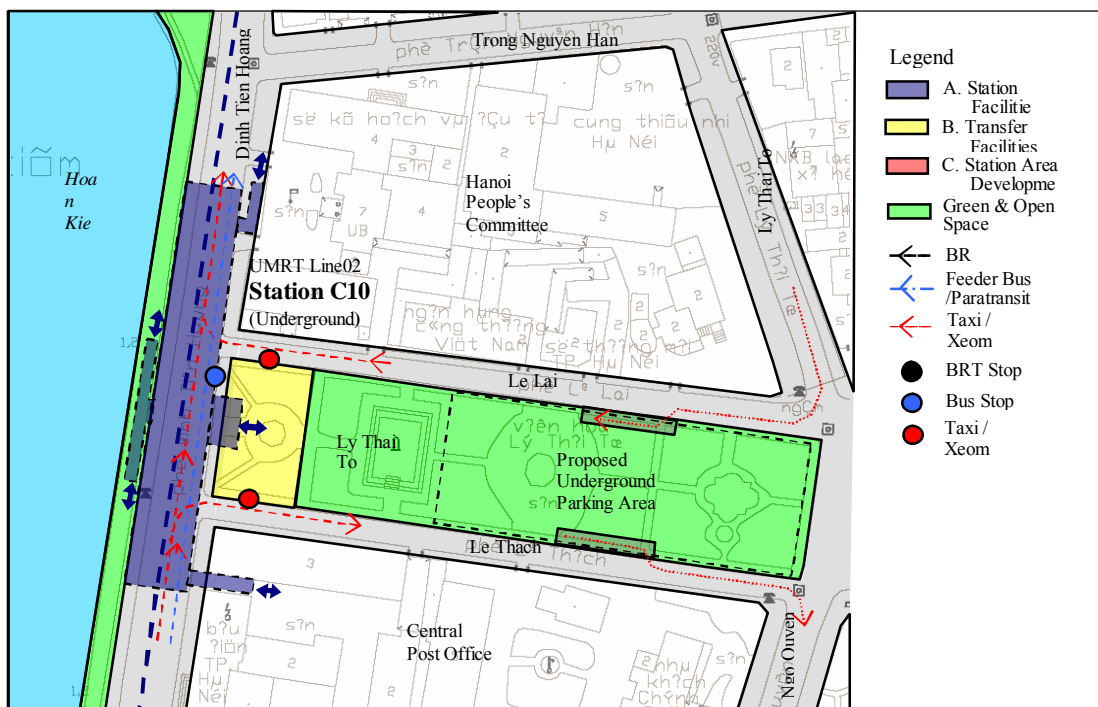


Source: HAIDEP Study Team

(7) Station C10: Hoang Kiem Lake Gateway

The proposed station C10 is located in front of the Hoang Kiem Lake, the Hanoi Peoples Committee, including the CBD and other governmental facilities which are one of the most famous destinations in Hanoi for local and international visitors. The station area is expected to promote and enhance attractiveness of this destination in conjunction with UMRT Line 2 station development through formulation of pedestrian-friendly streets with traffic management in the area, taking account of well-organized landscape and urban design.

Figure 3.5.11 Development Image for C10 Station and its Station Area

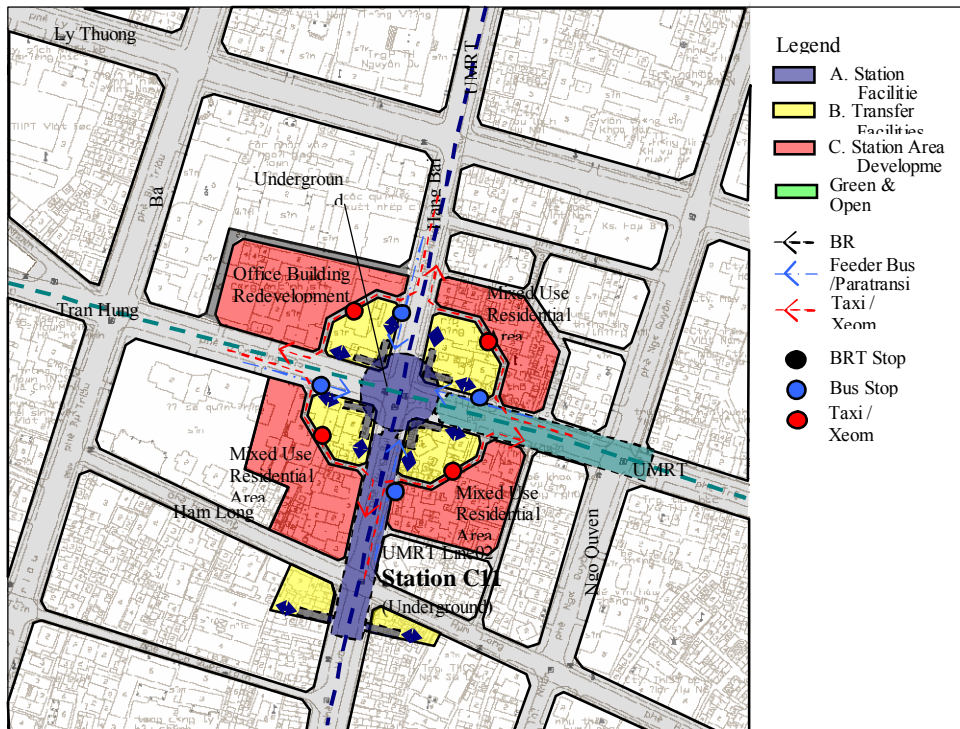


Source: HAIDEP Study Team

(8) Station C11: French Quarter Gateway

The proposed station C11 is located in the middle of the French Quarter under urban development control and regulation, where central government offices and embassies remained mainly as old colonial style buildings. These have formed the CBD of Hanoi city. The station area is expected to promote and enhance attractiveness and competitiveness of the traditional potential of the CBD in conjunction with UMRT Line 2 station development, taking account of well-organized landscape and urban design.

Figure 3.5.12 Development Image for C11 Station and its Station Area

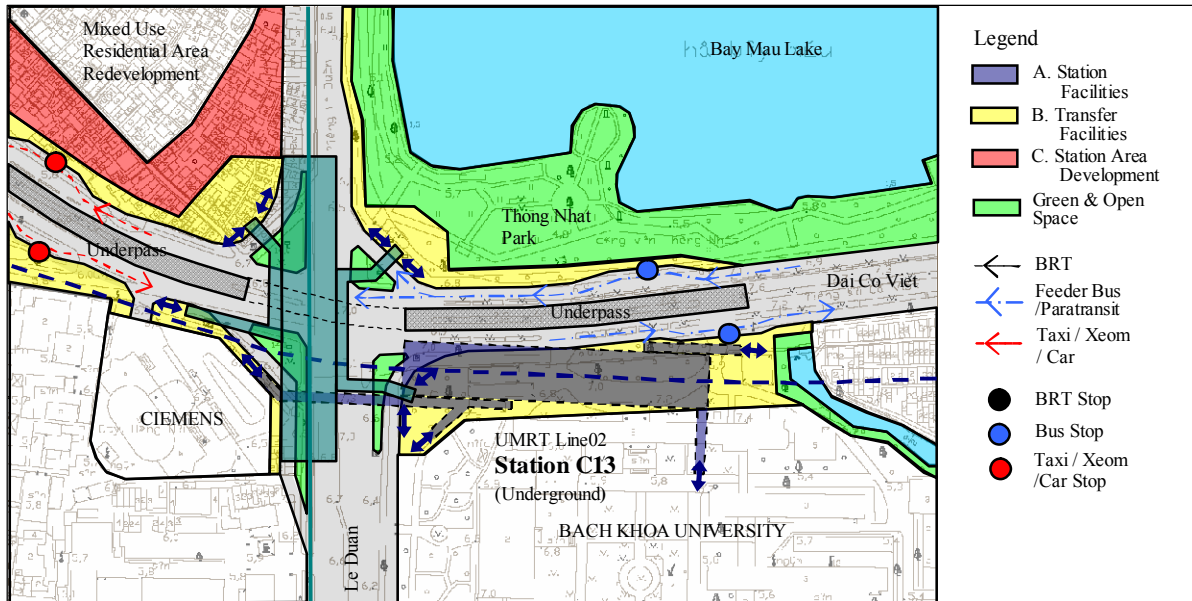


Source: HAIDEP Study Team

(9) Station C13: Bach Khoa University and Thong Nhat Park Gateway

The proposed station C13 is located in the intersection of primary roads of Dai Co Viet and Le Duan Street, where Thong Nhat Park and Bach Khoa University become main destinations of this station. There are two transportation plans regarding the intersection. The proposed station of UMRT Line 1 needs to be considered as a transfer station and the underpass of Dai Co Viet Street crossing Le Duan Street which will affect the location of station C13 and its alignment. The station vicinity area is expected to enhance convenient transfer between transportation modes of UMRT lines and feeder transportation in conjunction with UMRT Line 2 station development. Also UMRT Line 1 where redevelopment along railway will be necessary, should be formulated adequate urban development utilizing potential value for commercial and business area.

Figure 3.5.13 Development Image for C13 Station and its Station Area

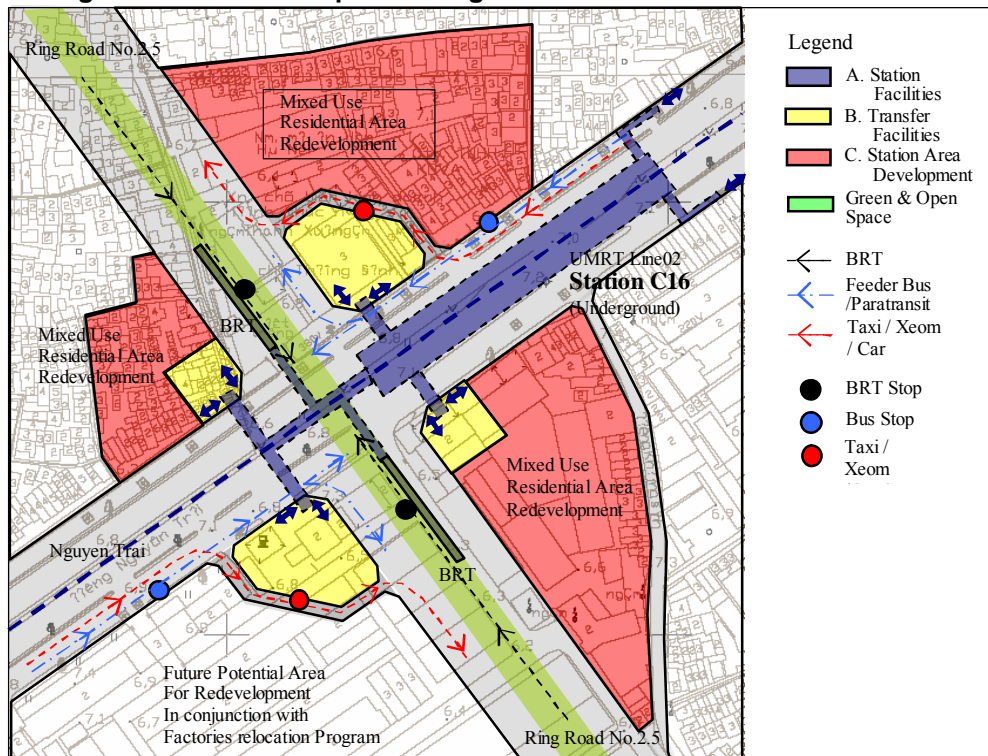


Source: HAIDEP Study Team

(10) Station C16: Thuong Dinh Area

The proposed station C16 is located in the planned intersection of primary roads of Nguyen Trai and the planned new street with BRT system as the Ring Road 2.5 extended from Trung Kinh Street, where large factories and old collective housing (KTT) are scattered along Nguyen Trai Street. The station area where old factories are required to relocate to suburban area and old collective housing area will be necessary for renewal and to formulate mixed use urban redevelopment utilizing potential value for commercial and business activities in combination with densely residential area.

Figure 3.5.14 Development Image for C16 Station and its Station Area

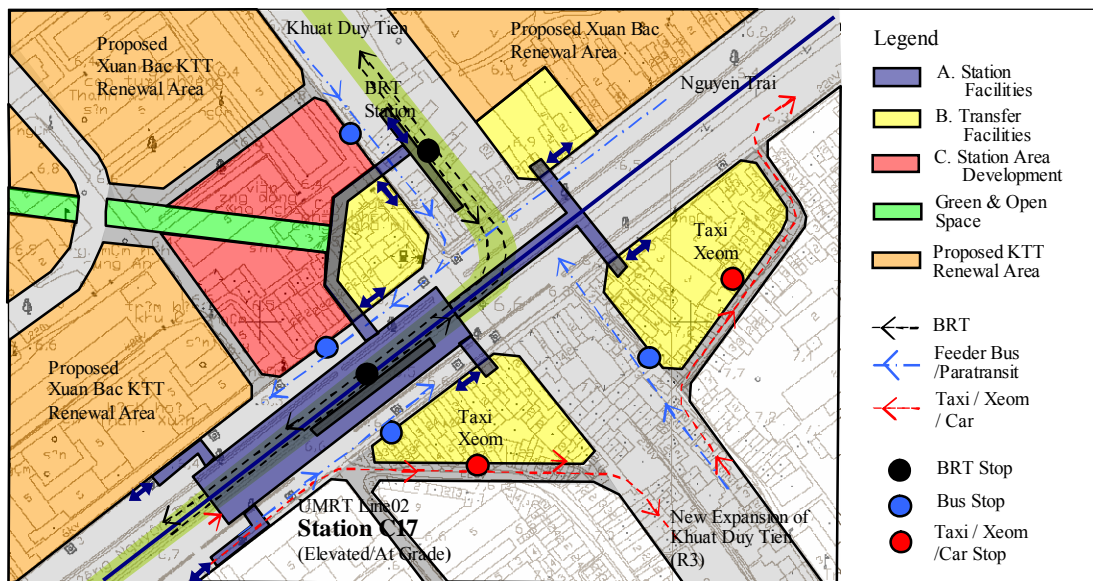


Source: HAIDEP Study Team

(11) Station C17: Xuan Bac and Xuan Nam Area

The proposed station C17 on the same NH6 Corridor (Nguyen Trai Street) as the station C16 is located at the planned intersection of primary roads of Nguyen Trai and the planned new street with BRT system (World Bank), whereas the Ring Road 3 extends from Khat Duy Tien Street, where large factories and old collective housing (KTT) are scattered along Nguyen Trai Street. The station area where old factories are required to relocate to suburban area and old collective housing area will be necessary for renewal and to formulate mixed use urban redevelopment utilizing potential value for commercial and business activities in combination with densely residential area.

Figure 3.5.15 Development Image for C17 Station and its Station Area



Source: HAIDEP Study Team

3.6 Airport Express Service

Increasingly railway connections to airports have become popular, in fact very necessary. This is due to rapid increases in air travel and associated congestion on road networks to/from airports. This trend is likely to continue, particularly in Asia, where growth in business and commerce, tourism and domestic air travel is expected to be robust. Hanoi is no exception and Noi Bai Airport will experience increasing pressure on its road connections.

As the alignment of UMRT Line 2 runs close to the existing Noi Bai International airport it is logical to incorporate the high speed airport connection into the project scope of UMRT Line 2 or an extension to the commuter transit system. A rail service needs to be considered.

There are a number of options, namely:

- (i) A dedicated service, with its own identity, trains and alignment/stations
- (ii) An extension of the Line 2 domestic service
- (iii) Dedicated trains, but using the domestic service alignment, with less frequent stops.
- (iv) Mixture of dedicated trains and domestic service trains.

A dedicated service is aspired and would add prestige, but would not be economically viable. It would require a separate route generally alongside the Line 2 alignment, its own stations, additional crossing of the Red river and special trains. Even if premium fares were charged, it is unlikely to ever be able to cover operating costs and certainly not the capital cost.

A five kilometer extension of Line 2 would take the domestic service to the airport. It could provide a frequent headway. However the time to the center of Hanoi would be around 38 minutes, because of the frequent station stops en route. Not all air passengers would be disadvantaged; however, the more frequent stops might get them closer to their destination point. The trains themselves however would not have much space for luggage, and this could at peak periods be a difficulty. Fares would be at same level as the domestic journeys. Overall, this option is viable economically but does not offer an enhanced service, due to the journey time.

A further option would be to utilize the Line 2 alignment, but to use dedicated trains, with less frequent stops and where possible have passing loops for the airport trains to overtake domestic trains. The stopping stations would have their own platforms to allow air passengers with baggage more time to ingress/egress. The trains could be designed to suit air passengers, with comfortable seating and more space. A premium fare could be charged. The difficulty with this option is that from around Nam Thang Long to Hoan Kiem the train speed would be the same as the domestic service and without passing loops the advantage of less station stops would be lost. The construction of passing loops in Phase 1 of Line 2 would add a substantial cost to the project and at peak times their advantages may in any event be negated. North of the Red river where station distances are greater and higher speeds possible, the airport trains would gain time. It is estimated that a journey time of 30 minutes would be possible from airport to Hoan Kiem.

A mixture of domestic trains and dedicated airport trains seems to offer no advantage, other than one i.e. a comfortable train, a little faster, less stops versus a more crowded train with few seats and little space for luggage. It is doubtful whether sufficient

passengers would be prepared to pay more for this luxury.

The most economical would appear to be to extend the domestic service of Line 2. This would provide a frequent service, require less infrastructure and no special trains. The number of trains required for this extension is also small, around 2x6 car trains for a 11 minute headway initially (this headway dictated by alternate trains going beyond Thai Phu)

The operation schedule envisaged would be a limited stop service from the airport to Hanoi City Terminal.

Within the scope of the initial phase will be the basic construction of the city airport terminal near Hoan Kiem lake. The design of the initial system should therefore include provision for this future requirement in the basic design of the Hanoi City Terminal.

3.7 Administration and Operations Control Center Location

In order to operate a modern transit system there will be a need to include an administration building and an Operations Control Center (OCC) along the route of UMRT Line 2.

The following locations for Administration Building and Operations Control Center (OCC) have been identified by the study team within the initial phase of the system, these are:

- (i) Tu Liem
- (ii) Long Bien
- (iii) Bach Khoa

If the depot is located at Tu Liem the railway administration and OCC can be located within the same complex. While the proposed Tu Liem Site is at the most northern end of the initial system; in the future the site, will be approximately at the midpoint of the final UMRT Line 2 system and therefore will be situated for the ultimate transit system.

In the short term the site is a little remote from the central area of Hanoi and lacks road access and utility services. However, if this is provided this would be the chosen site as land prices in this area will be less than that of central Hanoi.

On the downside, communications with other transit systems including UMRT Lines 1 & 3 and Vietnam Railways will be slightly more difficult than other suggested locations.

If the Administration building and OCC are located at Long Bien Multimodal the advantages would be easy connectivity between UMRT Line 1 and VR systems. Land prices would be more expensive at this location and thereby prompt urban renewal of the area. However delays in land clearances and resettlement may make this site unattractive as the site may not be available early enough in the initial rail system commissioning program.

Bach Khoa operationally has similar comments as per Long Bien multimodal but land prices may be a little less expensive and there would be more difficult connectivity with UMRT Line 1 & VR systems. Another problem is land availability.

Tu Liem Depot therefore would be the preferred site of the Administration & Operations Control building due to its more central location on the final UMRT Line 2 system. Future depot maintenance and vehicle storage sites have been identified and will be constructed dependent on the railway development schedule.

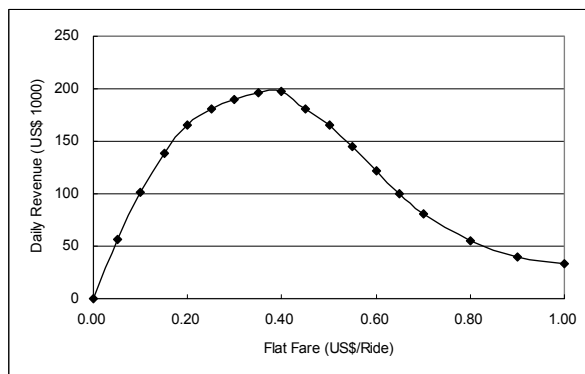
3.8 Ridership Forecasts

(1) Line Volume

Demand for the UMRT Line 2 is affected by other transport projects. In this forecast, all the other projects (except other UMRTs) proposed in HAIDEP Master Plan are assumed to be implemented following the proposed schedule, that is, the demand for the UMRT Line 2 was forecasted in the future HAIDEP network.

Another influential factor is the fare system of the urban railway. Before setting the fare, the demand and revenue were analyzed under various fares. Figure 3.8.1 shows the change of daily revenue of the phase one line of UMRT Line 2 in 2020, by changing fare level, where a flat rate was assumed. The revenue is maximized at the fare rate of US\$ 0.40 (about VND 6,400).

Figure 3.8.1 Daily Revenue Under Various Flat Fare



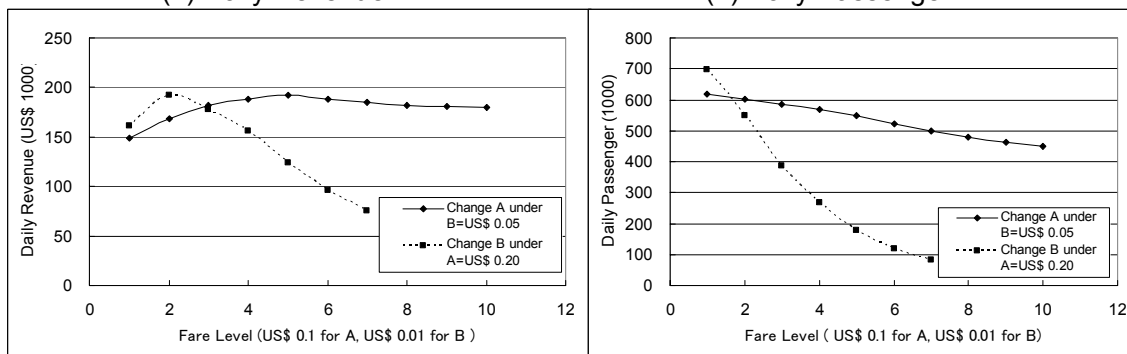
Source: HAIDEP Study Team

A distance proportional fare was tested wherein the fare was assumed as constant (flat) fare for the first four kilometer and beyond 4.0 km, a fixed amount was charged to additional one kilometer exceeding 4.0 kilometer. Then, the fare is given by the following formula.

$$\text{Fare of UMRT Line 2} = A + B \times (\text{Distance} - 4.0)$$

By changing A (constant) and B (gradient), the demand and revenue were estimated as shown in Figure 3.8.2. Firstly, the parameter B was assumed at US\$ 0.05 and changing the parameter B, the revenue was maximized when A was US\$ 0.02. Secondly, fixing the value of A at US\$ 0.20 and changing B, the revenue was maximized at US\$ 0.05 of B. Thus, the revenue will be maximized at US\$ 0.20 of A and US\$ 0.05 of B. These fare level will sacrifice the potential demand under free of charge by 20% to 25%.

Figure 3.8.2 Daily Revenue Under Various Flat Fare
 (1) Daily Revenue (2) Daily Passenger



Source: HAIDEP Study Team

The analysis revealed that the average distance of UMRT usage is about 6.4 km per passenger, of which fare is US\$ 0.52 (VND 8,300). This fare level is considered reasonable as the UMRT fare in 2020, comparing to the current bus fare of VND 3,000 per ride.

Given the conditions stated above, the demand of UMRT Line 2 was forecasted by development phase for the benchmark year 2020 and 2040. The result is shown in Table 3.8.1.

Table 3.8.1 Line Demand of UMRT Line 2 by Phase in Benchmark Years

Year	Phase	Section	Total Length (km)	Daily Passenger (Pax, Both Direction)	Trip Length (km)	Fare Revenue (\$US 000 /day)
2020	Phase 1A	Tu Liem-Bach Khoa	10.8	605,000	5.3	175
	Phase 1	Tu Liem-Thuong Dinh	14,6	693,000	5.7	215
	Phase 2	Nam Thanh Long-Ha Dong	24.4	968,000	6.5	339
	Phase 3	Depot 3-Ha Dong	36.6	1,050,000	8.2	483
	Phase 4	Noi Bai Airport-Ha Dong	41.8	1,130,000	8.4	520
2025	Phase 1A	Tu Liem-Bach Khoa	10.8	880,000	5.5	264
	Phase 1	Tu Liem-Thung Dinh	14,6	1,003,000	5.9	321
	Phase 2	Nam Thang Long-Ha Dong	24.4	1,435,000	6.7	517
	Phase 3	Depot 3-Ha Dong	36.6	1,572,000	8.4	739
	Phase 4	Noi Bai Airport-Ha Dong	41.8	1,720,000	8.5	799

Source: HAIDEP Study Team

Using the demand in the benchmark years, annual demand are interpolated by fitting logistic curves, because each line demand is almost reaching 90% of line capacity in 2040. The results are shown in Table 3.8.2 and Figure 3.8.3. If attaining 1.7 million passengers a day in 2040, UMRT Line 2 with 42 kilometer extension will be one of the busiest urban railway lines in the world.

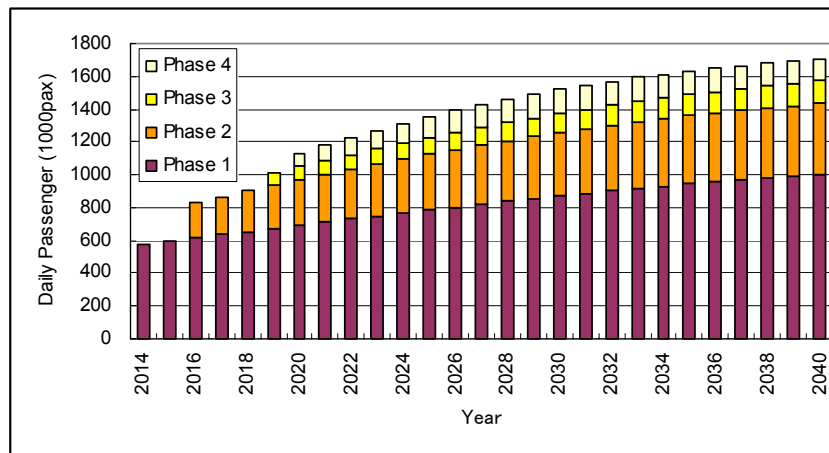
Table 3.8.2 Passenger Patronage of UMRT-2

(000 passenger/day)

Year	Phase 1	Demand Increase by Extension			Total
		Phase 2	Phase 3	Phase 4	
2014	575				575
2015	595				595
2016	615	217			832
2017	635	232			866
2018	654	246			901
2019	674	261	78		1012
2020	693	275	82	80	1130
2021	712	289	86	91	1178
2022	731	302	90	102	1225
2023	750	315	94	111	1269
2024	768	327	97	120	1312
2025	786	338	101	127	1352
2030	870	386	117	146	1519
2035	943	416	129	147	1635
2040	1003	432	137	148	1720

Source: HAIDEP Study Team

Figure 3.8.3 Trend of Passenger Increase of UMRT-2



Source: HAIDEP Study Team

(2) Station Patronage

The transportation model has predicted the daily passenger flows (boarding and alighting) per direction along the UMRT Line 2 route corridor for a number of development stages and for year 2020 and 2040.

In determining predicted passenger flows a number of development scenarios have been considered. While the maximum station passenger flows are generally predicted to occur in forecast year 2040, some stations temporarily experience maximum passenger flows in the shorter term, when the central city rail UMRT Line 2/ Phase 1 system is completed (forecast year 2020). In particular, these stations are the temporary terminal stations at Tu Liem and Thuong Dinh.

Predicted passenger volumes under various staged development scenarios following the completion of UMRT Line 2/Phase 1 leading up to the completion of the whole UMRT Line 2 system also show temporary increased patronage during this phased system development. However, these volumes are generally within 10% variance of the forecast 2040 flows when the UMRT Line 2 is fully completed. For the purposes of this report these variances have been ignored.

While Tu Liem and Thuong Dinh will ultimately be multimodal stations, at completion of Phase 1 development (2013) they will also be temporary terminal stations at which time they will attract temporarily higher passenger flows compared to the completed system in forecast years 2020 and 2040. Therefore, it will be necessary to consider these relatively shorter term flows when considering the station designs.

(a) Phase 1 System

The UMRT Line 2 Phase 1 is planned to be completed by 2013. Accordingly stations need to be designed to accommodate maximum predicted patronage flows at this time (equivalent to forecast year 2020) and forecast year 2040.

The Phase 1 predicted 2020 daily passenger patronage (boarding and alighting) per direction (down-line and up-line) for the stations which are given below:

Table 3.8.3 Daily Patronage 2020-Phase 1

No.	Station	Down (pax/day)		Up (pax/day)	
		Boarding	Alighting	Boarding	Alighting
1	Tu Liem ¹⁾	146,790	0	0	148,595
2	Intermediate ¹⁾	38,572	19,741	19,061	39,211
3	Ba Dinh	15,122	24,277	24,189	16,173
4	Intermediate	7,660	16,781	16,674	7,787
5	Intermediate	n/a	n/a	n/a	n/a
6	Long Bien	61,974	53,178	57,683	63,030
7	Airport City Terminal	2,408	4,327	4,301	2,393
8	Hoan Kiem	5,848	43,163	43,568	5,858
9	Intermediate	12,655	22,691	22,539	12,619
10	Bach Khoa	14,071	46,001	46,024	14,070
11	Intermediate	3,586	9,256	9,313	3,597
12	Intermediate	4,148	24,221	24,566	4,138
13	Thuong Dinh ¹⁾	0	40,032	40,240	0

Source: HAIDEP Study Team

1) Stations affected by temporary high patronage.

(b) Completed System

The UMRT Line 2 system (from Noi Bai to Ha Dong) is due for completion by 2020. Accordingly, in addition to the predicted patronage at 2020 for Phase 1 of the system, stations shall also be designed for patronage flows in years 2020 and 2040 for the completed system. The latter predicts the greater patronage.

The predicted 2040 daily passenger patronage (boarding and alighting) per direction (downline and upline) for the Phase 1 stations when the system is completed is given below:

Table 3.8.4 Daily Patronage 2040-Full System

No.	Station	Down (pax/day)		Up (pax/day)	
		Boarding	Alighting	Boarding	Alighting
1	Tu Liem ¹⁾	69,036	6,795	6,660	71,648
2	Intermediate ¹⁾	17,587	29,975	35,490	18,781
3	Ba Dinh	16,202	70,932	66,401	17,483
4	Intermediate	9,749	34,988	34,959	9,675
5	Intermediate	n/a	n/a	n/a	n/a
6	Long Bien	107,573	84,870	93,723	109,085
7	Airport City Terminal	2,591	4,826	4,803	2,575
8	Hoan Kiem	8,329	73,274	73,986	8,274
9	Intermediate	20,189	40,978	40,581	20,131
10	Bach Khoa	27,724	79,832	79,676	27,935
11	Intermediate	5,891	12,275	12,329	5,914
12	Intermediate	29,716	36,325	36,544	29,197
13	Thuong Dinh ¹⁾	2,593	7,977	7,991	2,596

Source: HAIDEP Study Team

1) Stations affected by temporary high patronage

(c) Maximum Daily Passenger Demand

From Table 3.8.3 and 3.8.4, the following stations exhibit greater daily demand in the temporary condition (Phase 1) in year 2020 relative to the complete system in forecast year 2040:

- (i) Tu Liem;
- (ii) The intermediate station south of Tu Liem; and
- (iii) Thuong Dinh.

Therefore, in determining station peak patronage demands, Table 3.8.5 showing maximum daily passenger flows per direction has been used.

Table 3.8.5 Maximum Design for Daily Patronage

No.	Station	Down (pax/day)		Up (pax/day)	
		Boarding	Alighting	Boarding	Alighting
1	Tu Liem ¹⁾	146,790	0	0	148,595
2	Intermediate ¹⁾	38,572	19,741	19,061	39,211
3	Ba Dinh	16,202	70,932	66,401	17,483
4	Intermediate	9,749	34,988	34,959	9,675
5	Intermediate	n/a	n/a	n/a	n/a
6	Long Bien	107,573	84,870	93,723	109,085
7	Airport City Terminal	2,591	4,826	4,803	2,575
8	Hoan Kiem	8,329	73,274	73,986	8,274
9	Intermediate	20,189	40,978	40,581	20,131
10	Bach Khoa	27,724	79,832	79,676	27,935
11	Intermediate	5,891	12,275	12,329	5,914
12	Intermediate	29,716	36,325	36,544	29,197
13	Thuong Dinh ¹⁾	0	40,032	40,240	0

Source: HAIDEP Study Team

1) Stations affected by temporary high patronage.

(3) Peak Passenger Demand

In order to carry out spatial planning of the stations it is necessary to have the following passenger demands:

- AM Peak Hour boarding and alighting
- PM Peak Hour boarding and alighting

A number of assumed factors have been applied to the maximum daily passenger flows to derive these peak passenger demands which are described below.

Since the predicted passenger flows which are derived from the transport model are the predicted maximum daily passenger flows (boarding and alighting) at station locations in forecast years 2020 and 2040, it is necessary to convert these maximum daily passenger flows to peak hourly flows.

Also, in order to assess passenger flows on the down-line and the up-line within the same peak period it is also necessary to assess the potential off-peak hourly flows on one line which may be coincident with peak hourly flows on the other line during this same peak period.

For the purposes of this study the following design peak factors have been assumed:

- Peak hourly flow = 0.16 x maximum daily (boarding/alighting) passenger flow
- Off-Peak hourly flow = 0.05 x maximum daily (boarding/alighting) passenger flow

It is assumed that the maximum daily passenger flows (boarding and alighting) per direction at each station will result in peak hour demands in each direction which are not necessarily occurring in the same peak period.

It is considered that to assume the peak hourly demand (boarding and alighting) in each direction is occurring in the same peak period may be overly conservative for a number of stations and therefore could result in unreasonably conservative spatial requirements within stations.

Intuitively, it is assumed that during the AM Peak Hour passenger flows are directed towards the inner city while in the PM Peak Hour passenger flows are directed in the opposite direction, that is, from the inner city area towards the outer areas of UMRT Line 2.

A similar approach has been adopted for the PM peak hour.

Using the maximum daily passenger flows per direction and the peak hour distribution matrix the AM and PM peak hour passenger demands in each direction have been determined.

From the above, the peak hourly boarding and alighting passenger flows in each direction can be summated to determine peak hourly station flows as indicated below:

Table 3.8.6 Peak Hourly Station Demand¹⁾

No.	Station	AM Peak (pph)		PM Peak (pph)	
		In	Out	In	Out
1	Tu Liem ²⁾	23,486	7,430	7,340	23,775
2	Intermediate ²⁾	7,125	5,119	4,978	7,261
3	Ba Dinh	13,216	14,146	13,216	6,344
4	Intermediate	7,153	7,146	7,153	3,297
5	Intermediate	n/a	n/a	n/a	n/a
6	Long Bien	32,207	31,033	32,208	19,033
7	Airport City Terminal	1,183	1,184	1,183	901
8	Hoan Kiem	13,171	13,048	13,171	12,138
9	Intermediate	9,723	9,777	9,723	7,563
10	Bach Khoa	14,134	17,243	17,184	14,170
11	Intermediate	2,735	2,260	2,314	2,705
12	Intermediate	7,333	6,488	6,582	7,272
13	Thuong Dinh ²⁾	6,438	2,002	2,012	6,405

Source: HAIDEP Study Team

1) In pph or person per hour.

2) Stations affected by temporary high patronage.