3.5 Maintenance Center

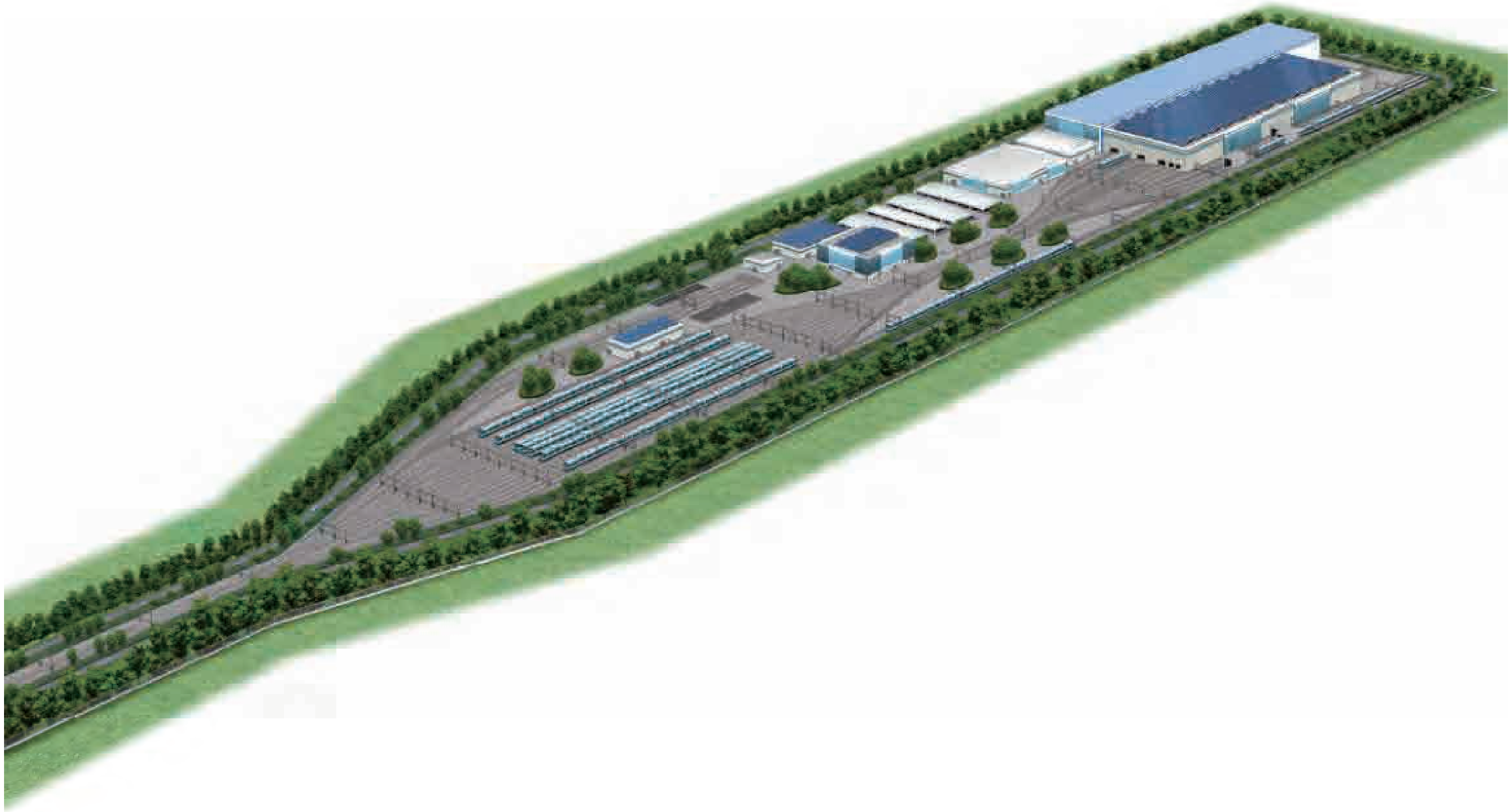
3.5.1 Basic concept

Recently in Japan, acquisition of railway sites is increasingly difficult, and a concept to combine technical support related facilities such as the track base, electrical base, and rolling stock depot, which were conventionally located in separate locations in a single location as the maintenance center has become popular. For Line 5, the concept that all departments including headquarter will be located in the maintenance center will be introduced.

Table 3.5.1 Outline of the Maintenance Center for Line 5

Use	Site Area (m^2)	Building Area (m^2)	Principal Buildings
Rolling stock zone (including depot)	100,000	30,000	Rolling stock inspection building (single story steel frame) Associated workshops (single story steel frame, etc.) Office (RC) Auxiliary buildings (single or two story steel frame) Train operation office (RC)
Materials zone	10,000	3,000	Materials warehouse (single story steel frame (stacking type)) Hazardous goods warehouse (concrete block single story)
Civil and electrical works zone	10,000	2,000	Office (RC) Warehouse (steel frame) Rolling stock inspection (Single story steel frame building) Substation
Perimeter road and buffer zone	50,000		
(Total area)	170,000	35,000	

Source: JICA Study Team



Source: JICA Study Team

Figure 3.5.1 Maintenance Center for Line 5 (Image)

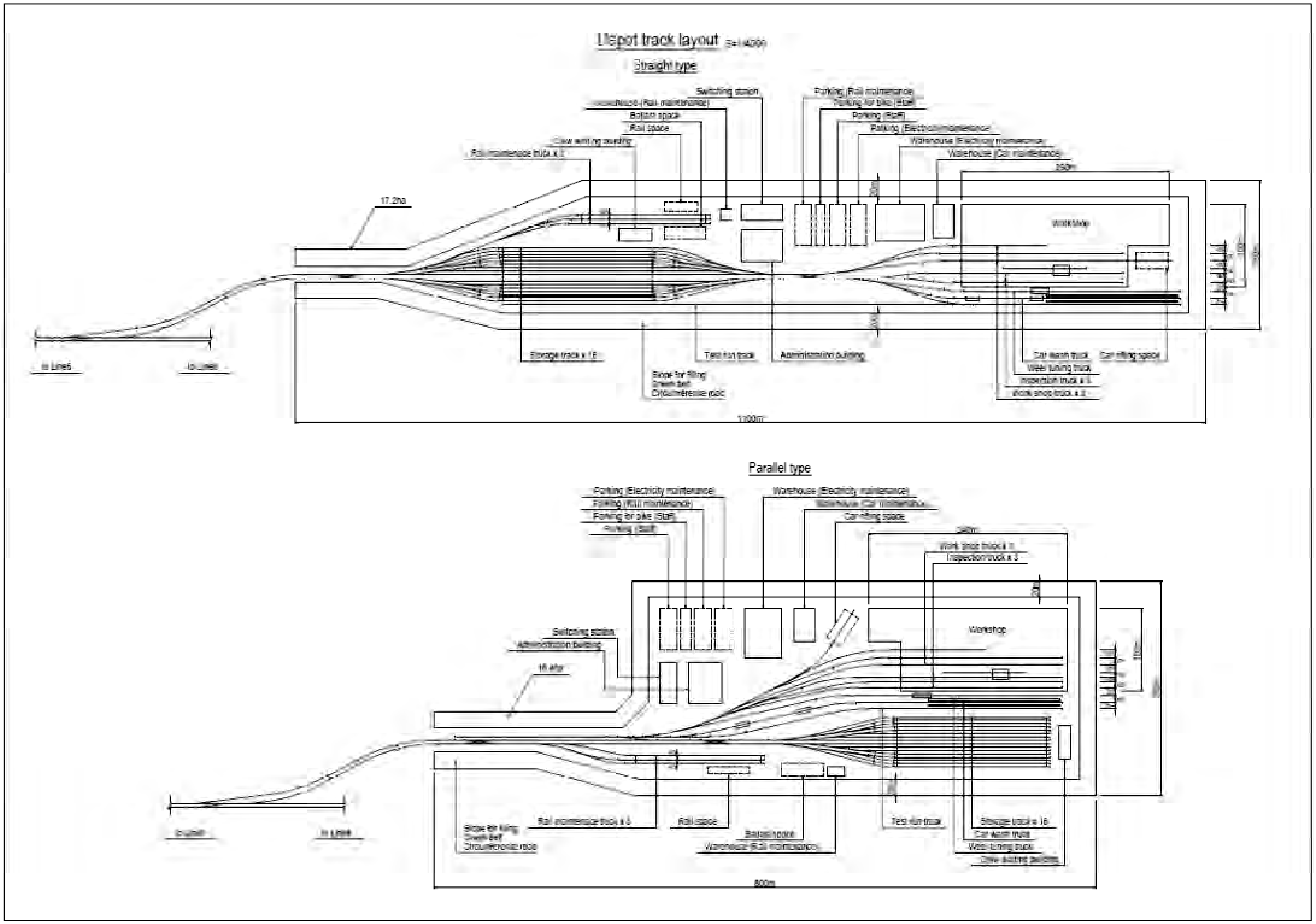


Figure 3.5.2 Maintenance Center for Line 5 Source: JICA Study Team

3.5.2 Rolling stock depot

A rolling stock depot consists of storage tracks where rolling stock used for the service on the operation lines are stored; inspection facilities where repairs of failures, inspection of rolling stock without overhauling, or replacement of consumables are made; and workshop facilities where overhauls and major inspections and repairs are made.

(1) Storage tracks

These tracks store the rolling stock to be ready for service on the operation lines. While storage capacity is dependent on the number of cars in the train formation and the number of trains in possession, anticipating increases in the rolling stock in the future, 16 tracks with a length of 180 m shall be installed from the beginning of the project, which will allow storage of eight-car train set on each track.

(2) Inspection facilities

Inspection facilities are where daily inspection of rolling stock without overhauling, cleaning, and light maintenance operations is made. Principal facilities and equipment are as follows.

1) Inspection pit track

Two inspection pit tracks shall be installed in the inspection building where ten-day inspections (performed once in a ten-day to two-week period, requiring one hour for one train set) and three-month inspections (performed once every three months, requiring a full day for one train set) are performed. The length of the pit shall be 180 m, which allows inspection of the full eight-car train set.

The length of the pit is to be extended from six-car train set in Phase 1 to eight-car train set in Phase 2. This will allow inspection of the extended train set of cars when passengers increase in the future.

Construction of the inspection pit track will allow a flat approach (without gradient) from the storage tracks by lowering the floor level of the entire inspection area from the track by the height of one step, which will allow inspection of the undercarriage in a comfortable position and allow free movement between inspection pit tracks in the transverse direction.

Inspection of the car body is done on the inspection platforms located alongside the track at the floor height of the train and another platforms located at the roof height of the train are used for inspection of equipment installed on the roof.

2) Extraordinary inspection track

A track that is used for the replacement of parts of the bogies shall be installed in the rolling stock inspection building, where the replacement of wheels, traction motors, etc., is made outside the periodic inspection. This track has the same structure as the inspection pit truck and allows overhaul and parts replacement of the bogie, which is detached from the car body using the lifter/traverser installed near the center of the extra inspection track.

3) Wheel lathe turning track

A track equipped with the under-floor type car wheel lathe used to correct wheel tread profile shall be installed. This facility allows correction of the tread profile without decoupling the train set and detaching the bogie from the body.

Source: JICA Study Team
Figure 3.5.3 Inspection pit track

Source: JICA Study Team
Figure 3.5.4 Under-floor type car wheel lathe (wheel lathe turning)

4) Car-washing track

A track equipped with the automatic car-washing equipment and platforms for body washing shall be installed. The washing machine that cleans both sides of the body with rotating brushes and the platforms are installed where manual cleaning of the body is done by workers. The length of the platforms shall allow cleaning of eight car train set.

Source: JICA Study Team
Figure 3.5.5 Car-washing track

5) Test run track

This truck is used to test run the train within the depot. To allow test runs at speeds exceeding the normal speed within the depot, the length of the track shall be 700 m.

(3) Workshop facilities

Workshop facilities are used to overhaul the train every four years and for major modification work every tens of years.

1) Overhaul track

This track is where the overhaul of the rolling stock once every four years takes place. The facility shall be designed to allow jacking up of the complete train set and detachment of bogies starting from the end of the train for inspection, which is a feature common to workshops constructed recently. For this purpose, jacks to lift each rolling stock are installed under the floor (under the ground). Inspection of the under-floor equipment of the rolling stock inspected shall be performed with workers standing on the flat surface (underground level) in a comfortable position.

A single overhaul track will be sufficient for overhauling trains for Line 5; however, considering the overhauling of trains of other lines, such as Line 8 in the future, two overhaul tracks shall be installed, both with a length for eight cars to avoid unnecessary decoupling of the train set and disconnection of equipment and circuits.

2) Alteration track

Because the rolling stock is used for long period of time, it is a normal practice for major modification work to take place in the middle of service life. A track where such modification work is performed shall be installed in the rolling stock maintenance building. The length of the track shall allow four cars considering the number of cars modified simultaneously.

3) Miscellaneous facilities and equipment

During the overhaul, the components and parts are disassembled and inspected, and various types of equipment used in maintenance of the components are required. Such facilities and equipment for example, include the bogie cleaning machine that cleans bogies of all accumulated dirt and dust, the wheel press-fit and removal machine that pulls out and insert wheels from and onto the axle, testers used for inspection of electrical equipment like controllers, and the inspection of pneumatic system equipment like brakes.

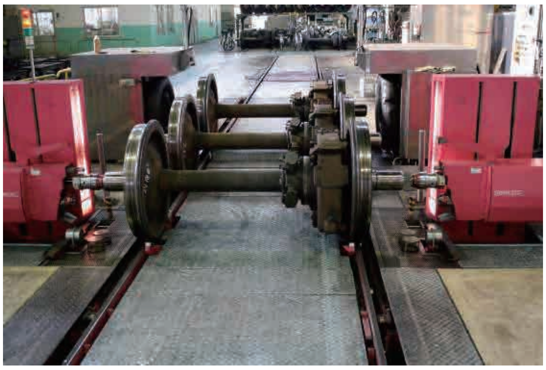
In addition, bogie traversers used to transport the bogie detached from the body, lift trucks and cranes used to transport heavy articles like traction motors, and a rail tractor to move unpowered rolling stock are also necessary.

Principal facilities and equipment in the workshop are as shown in the table below.

Table 3.5.2 Principal facilities and equipment in the workshop

Description	Function
Car body elevator equipment	Lifts up bodies of the train with its train set connected and the bogies are detached from the body
Wheel press-fit and removal equipment	Removes and installs a wheel from and onto the axle
Wheel lathe turning	Reworks wheel profile before it is installed on the axle
Automated ultrasonic testing system for the wheelset	Automatically detects a defect of the wheelset with ultrasonic waves
Overhead travelling crane	Lifts up and transfers heavy articles such as the traction motor and the bogie
Traverser	Transfers the bogie detached from the body in normal direction to the track
Bogie cleaning machine	Cleans the bogie of accumulated dirt and dust in overhaul
Waste water treatment system	Cleans the wastewater produced after cleaning of the bodies and bogies
Rail tractor	Tows the unpowered rolling stock

Source: JICA Study Team



Source: JICA Study Team

Figure 3.5.6 Automated ultrasonic testing system for the wheelset

Source: JICA Study Team

Figure 3.5.7 Wheel press-fit and removal equipment

Source: JICA Study Team
Figure 3.5.8 Rail tractor

Source: JICA Study Team
Figure 3.5.9 Bogie cleaning machine

3.5.3 Track base

This depot keeps the materials and equipment for track inspection and maintenance. Track maintenance personnel are also stationed here. A space to store materials for track maintenance (rails, sleepers, track ballasts, etc.) and the storage tracks for maintenance cars shall be located here. For Phase 1, a tamping machine that tamps and corrects ballasts, rail grinding machines, ballast wagons, and materials carriers are required for the maintenance car fleet. The rail carriers will be required in Phase 2.

3.5.4 Electrical base

This depot keeps the materials and equipment for inspection and maintenance of the overhead contact line, radio equipment, etc. Electrical maintenance personnel are also stationed here. For Phase 1, an overhead contact line inspection cart (unpowered) and aerial lift truck (road-rail vehicle) are required as the maintenance car fleet. After completion of Phase 2 construction, an overhead contact line inspection car is required.

3.5.5 Maintenance cars

Special maintenance cars for inspection of ground facilities like tracks, overhead contact line, signaling system, etc., after the start of train operation shall be procured. Principal maintenance cars required are as shown in Table 3.5.3.

Table 3.5.3 Principal maintenance cars

Description	Function
Track motorcar	Small powered vehicle used to transport personnel and materials for maintenance
Rail and PC crosstie carrier	Transports rails, cross-ties, and other materials to the work site
Track inspection car	Measures and records the (1) gauge, (2) cross level of the rails, (3) longitudinal level irregularity, (4) distortion of the rail, (5) twist of the track, etc. automatically and simultaneously.
Overhead contact line inspection car	Measures wear, height displacement, etc., of the overhead wire
Tamping machine	Corrects measurements of the track in millimeter order by lifting, moving the track laterally, and tamping ballasts beneath the cross-ties at high compacting force
Rail grinding machine	Corrects roughness on the rail surface to the cross-sectional shape of the new rail
Three-way dump cart	Driven by the track motorcar and transports soil and ballast

Source: JICA Study Team

Source: JICA Study Team

Figure 3.5.10 Tamping machine

Source: JICA Study Team

Figure 3.5.11 Track inspection car

Source: JICA Study Team

Figure 3.5.12 Rail grinding machine

Source: JICA Study Team

Figure 3.5.13 Rail and PC crosstie carrier

Source: JICA Study Team

Figure 3.5.14 Three-way dump cart

Source: JICA Study Team

Figure 3.5.15 Overhead contact line inspection car

3.6 Substations and Electrical facilities

3.6.1 Substation facility plan

(1) Electricity in Hanoi City, Vietnam

In July 2011, the Master Plan for National Electricity Seventh (PDP7, QD-201208-TTg) took effect upon approval by the Prime Minister, which specifies national electricity development plan from 2011 to 2020 under national electricity development vision towards 2030.

Study Team had received copies of "500-110 kV Electrical Power System Diagram in Hanoi (as of 2010)" (see Figure 3.6.1) and the "500-110 kV Electrical Power System Diagram in Hanoi (plan for the years up to 2015) and Direction towards 2020" which incorporates the plan of PDP7 (see Figure 3.6.2) from the Vietnam Electricity Holding Company (EVN).

While it is possible that a new master plan for national electricity may take effect and the electricity development plan may be changed or updated, Study Team completed planning of substation layout for the Line 5 based on Figure 3.6.2 in which the plan of PDP7 is incorporated.

According to Figure 3.6.2, EVN substations (existing and planned) shown in Table 3.6.1 will be located along the tracks of the Line 5 (within about 5 km from the track along the road).

Table3.6.1 List of EVN substations long the Line 5

Section	EVN substations		
	Existing	Planned (from year 2011 to 2015)	Planned (from year 2016 to 2020)
Phase1	・NGHIA DO ・GIAM ・THANH CONG ・THANH XUAN ・MY DINH	・BAC AN KHANH ・NAM AN KHANH	・CV.THULE
Phase2	・PHUNG XA ・THACH THAT	・QUOC OAI	・PHU CAT ・DAI HOC QUOC GIA ・LANG VAN HOA

Source: JICA Study Team

(2) Description of the electricity receiving plan

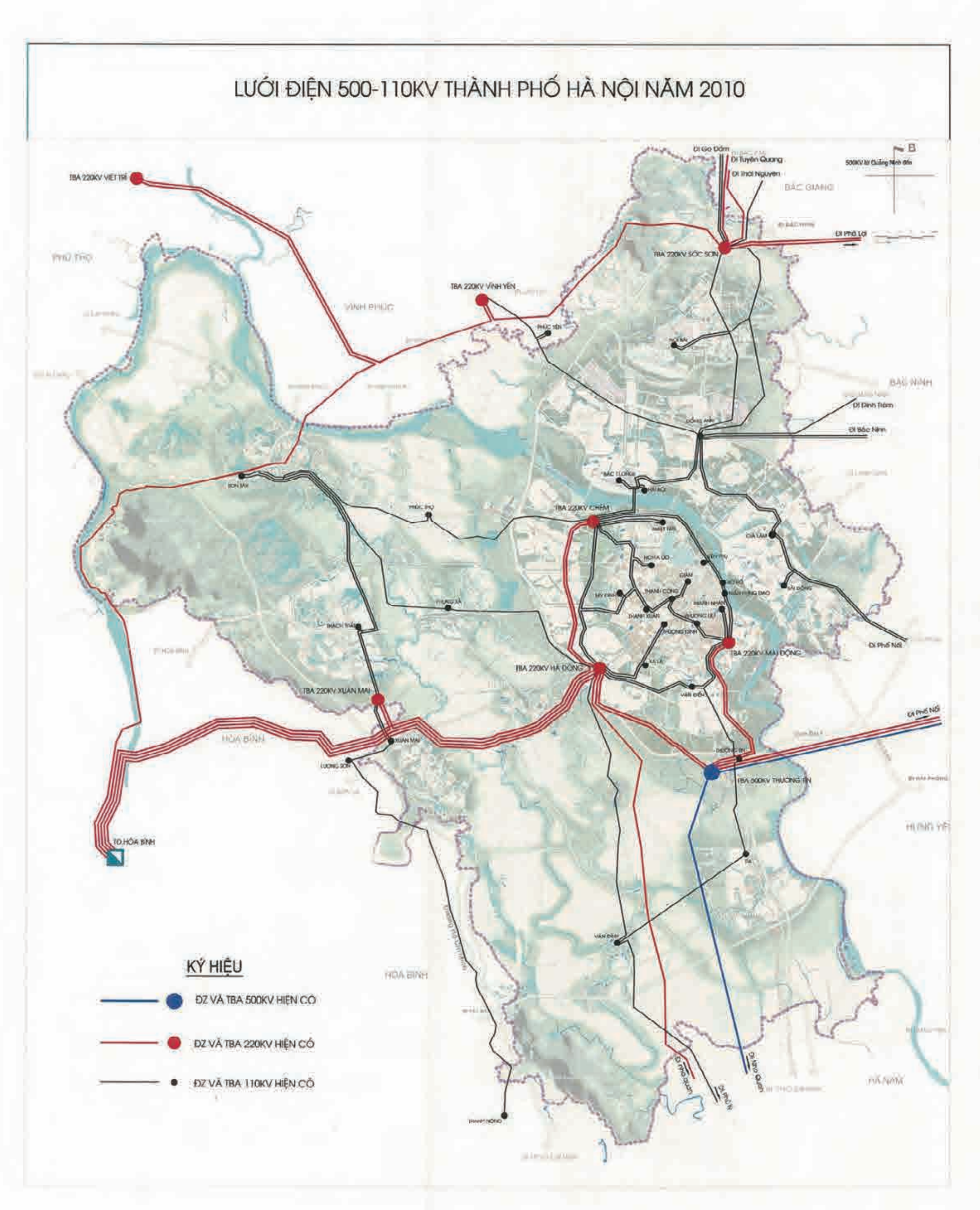
With respect to receiving plan of electricity for the Line 5, Study Team had a number of meetings with EVN, conducted survey of sites for the receiving substations and presented a description of the plan to the Hanoi Industrial and Trade Portal that manages the electricity plan for Hanoi. When the Line 5 construction project is approved and the project advances to design phase, a letter on the basic electricity receiving plan will be submitted from MRB to EVN Hanoi.

Table 3.6.2 Plan of receiving electricity for the Line 5 (planned)

Year	2021 (Phase1)	2030 (Phase2)	2035
Total capacity supply for each substation	39MVA	72MVA	87MVA

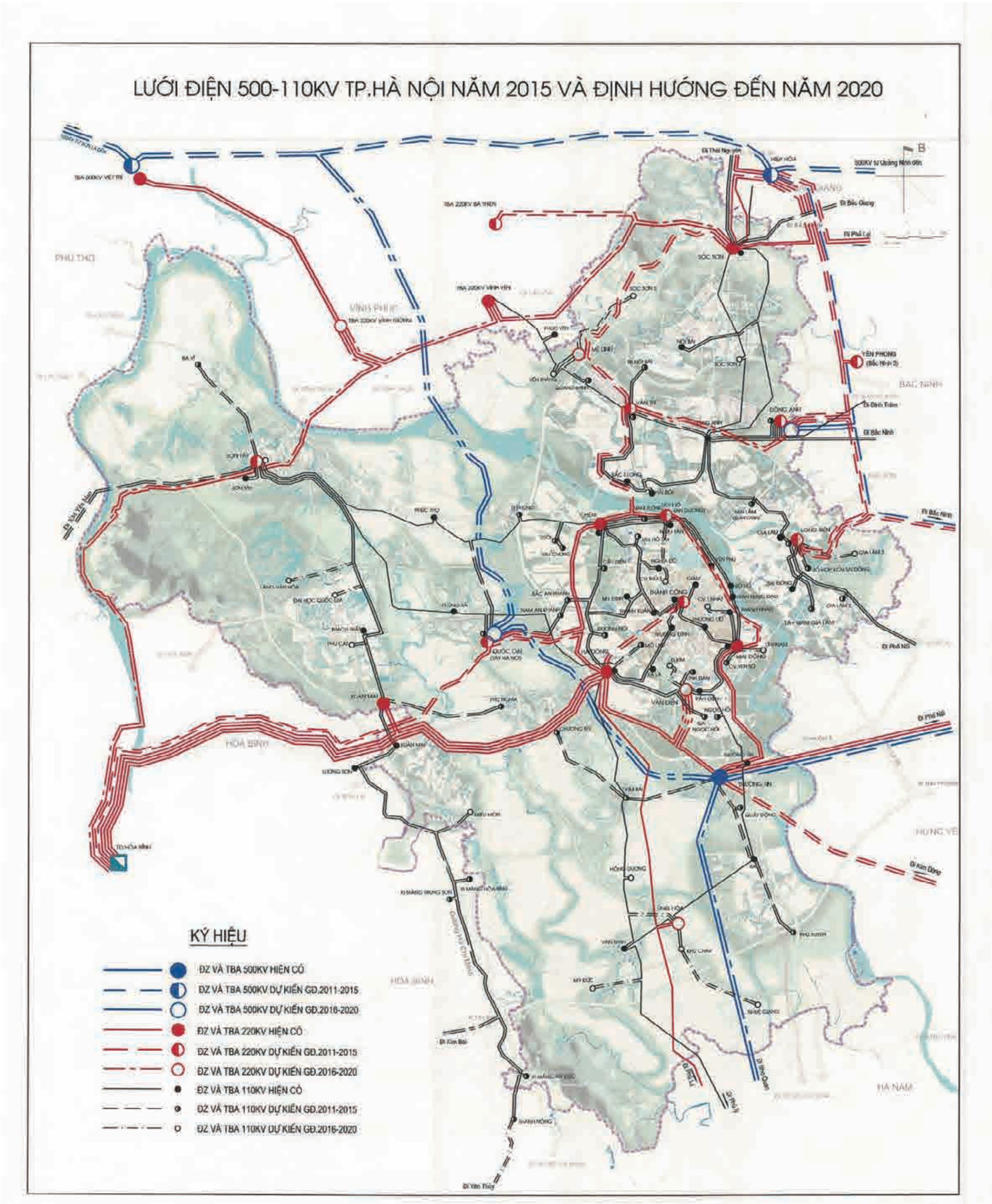
Source: JICA Study Team

(Remarks) in year 2021: St.1-St.9, 4 cars, year 2030: St.1-St.17, 6 cars, year 2035: St.1-St.17, 8 cars



Source: EVN

Figure 3.6.1 500-110 kV Electrical Power System Diagram in Hanoi (as of year 2010)



Source: EVN

Figure 3.6.2 500-110 kV Electrical Power System Diagram in Hanoi (plan for the years up to 2015) and Direction towards 2020

(3) Substation location plan for Line 5 (see Figure 3.6.3)

Substations for the Line 5 shall be located so that the operation of trains will not be affected when four-car sets (2M2T) is operated at six-minute intervals (morning peak commute hours) and, in the future, when eight-car sets(4M4T) is operated at five-minute intervals (morning peak commute hours).

With the above operation scheme as the condition, seven substations for the Line 5, three for Phase 1 (Line 5-(i) , Line 5-(ii), and Line 5-(iii)), three for Phase 2 (Line 5-(iv), Line 5-(v), and Line 5-(vi)), and one for Phase 3 (Line 5-(vii)) shall be located at the points shown in Table 3.6.3 considering voltage drops of DC 1500 V (standard voltage for the Line 5) between substations.

Among these seven Line 5 substations, three substations (Line 5-(i), Line 5-(iii), and Line 5-(vi)) shall be connected to the substations of EVN as the receiving substations and shall receive AC 22 kV (3 φ) via two private lines. AC 22 kV (3 φ) received from the EVN substations shall be supplied to other four Line 5 substations (Line 5-(ii), Line 5-(iv), Line 5-(v), and Line 5-(vii)) that are not connected to the EVN substation by way of private lines.

As for the substations of EVN to which connections shall be made, since there is no extra capacity in the existing substations, Line 5-(i) shall be connected to EVN substation CV.THULE to be constructed in 2016–2020, Line 5-(iii) shall be connected to BAC AN KHANH to be constructed in 2011–2015, and Line 5-(vi) shall be connected to PHU CAT to be constructed in 2016–2020.

The sites for Line 5 substations considered are the grounds under the elevated tracks for Line 5-(i), Line 5-(iii), and Line 5-(vi), a ground to the north of Thang Long road for Line 5-(ii), grounds between the frontage road and the north of Thang Long road for Line 5-(iv) and Line 5-(v), and a ground alongside the track for Line 5-(vii).

For the underground structure in urban area, Line 5-(i) substation shall be constructed under the ground.

Table 3.6.3 Line 5 substation location plan

Section	Line 5 Substations	Location (km point)	EVN Substations to be Connected	Line 5 Substations Proposed Construction Site
Phase 1	Line 5-(i)	2.0	CV.THULE	Ground under the elevated tracks
	Line 5-(ii)	8.6		Ground to the north of Thang Long road
	Line 5-(iii)	14.1 + (1.0)	BAC AN KHANH	Ground under the elevated tracks
Phase 2	Line 5-(iv)	19.1		Ground between the frontage road and the north of Thang Long Road
	Line 5-(v)	25.6		Ground between the frontage road and the north of Thang Long Road
	Line 5-(vi)	32.0	PHU CAT	Ground under the elevated tracks
	Line 5-(vii)	37.6		Ground near the tracks

Source: JICA Study Team

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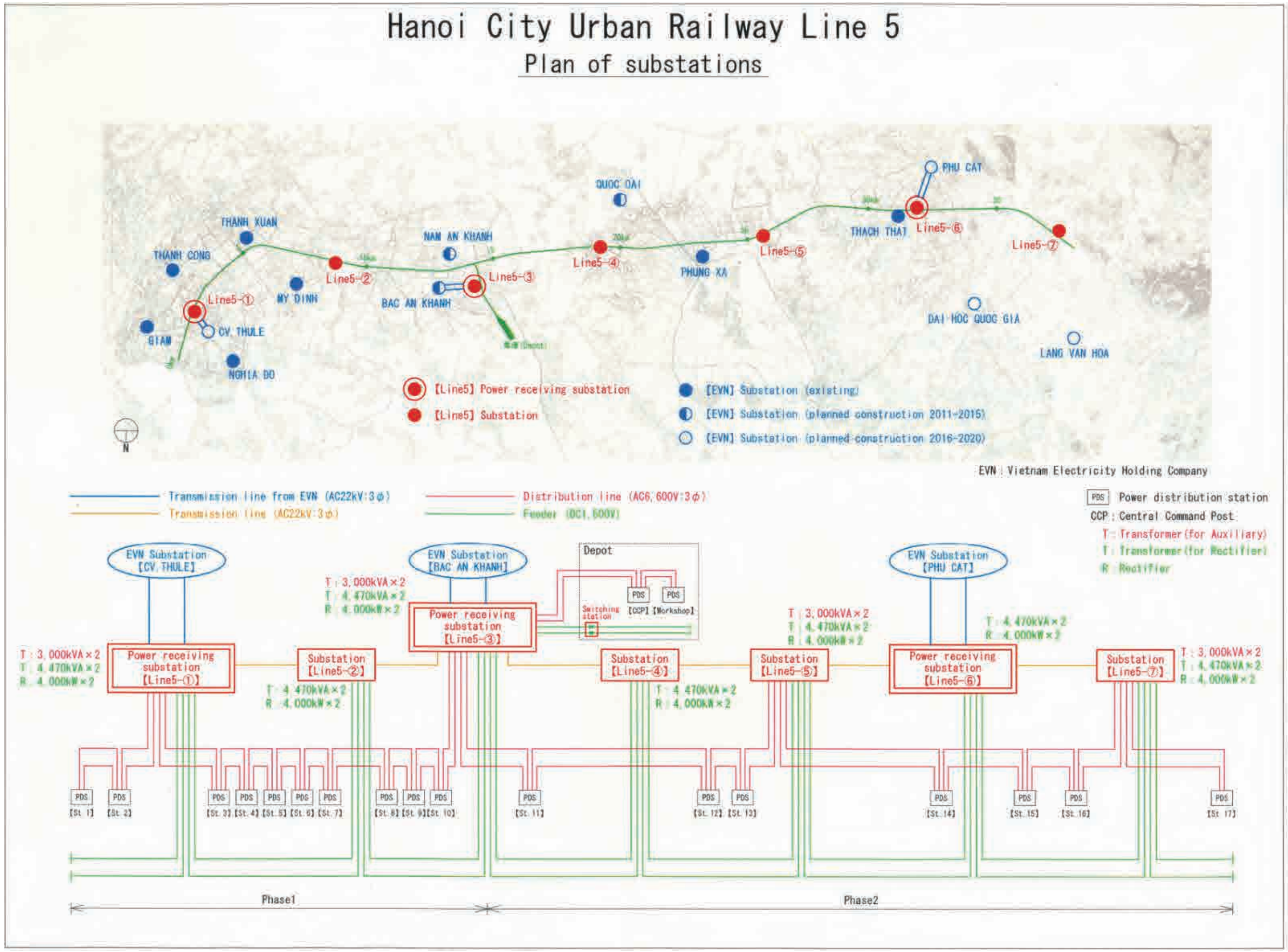


Figure 3.6.3 Planned location of substations for the Line 5 Source: JICA Study Team

(4) Substation facilities for Line 5 (see Figure 3.6.4)

1) Receiving and transmission facilities

(i) Power receiving facilities

Among the Line 5 substations in seven locations, three substations (Line 5-(i), Line 5-(iii), and Line 5-(vi)) shall be connected to EVN substations as the receiving substations at AC 22 kV (3 φ).

Receiving lines to be connected to EVN substations shall consist of two lines considering the need for power down to allow maintenance and inspection of the facility and possible power interruption due to failure of the receiving line. These two receiving lines shall be for exclusive use by Line 5 substations to avoid power failures due to the effect of electrical demand by other users. The configuration as the exclusive lines will allow preferential supply of electricity for railway service from EVN substations as in medical facilities even in the event of a scheduled power stoppage. The two receiving lines shall be installed as underground cables as a rule considering scenic requirement and installation costs where burying is controlled. Circuit breakers, disconnecting switches, arresters, instrumentation, etc., suitable for the use shall be installed as well.

When Study Team contacted EVN and MRB, all construction work, construction costs, maintenance, etc., for the entire receiving and transmission facilities with EVN substations and the substations for rail service shall belong to the electricity consumer side (the Line 5 side), so the costs shall be included in the construction expenses.

(ii) Power transmission facilities

AC 22 kV (3 φ) received from EVN substations shall be transmitted to four Line 5 substations (Line 5-(ii), Line 5-(iv), Line 5-(v), and Line 5-(vii)) that are not connected to EVN substations via private transmission lines. Using these private transmission lines, it is possible to distribute AC 22 kV (3 φ) to the respective Line 5 substations received from other two normally operating EVN substations when one of three EVN substations to which Line 5 substations are connected fails (for example, supply in both two receiving lines fails), and impact on train operation can be minimized. In addition, circuit breakers, disconnecting switches, arresters, instrumentation, etc., suitable for use shall be installed.

2) Direct current transformer facilities

The direct current transformer facility is the facility used to convert AC power to DC power and consists of rectifiers (3-phase double bridge connection (parallel 12-pulse), voltage fluctuation: 6%), transformers (for rectifier 22 kV/1,180 V), control equipment, and instrumentation.

Received AC 22 kV (3 φ) shall be converted to DC 1,500 V (full wave rectification) at seven Line 5 substations for train operation by the transformer (for rectifier 22 kV/1,180 V) and the rectifier (3-phase double bridge connection (parallel 12-pulse), voltage fluctuation: 6%).

The direct current transformer facilities shall be able to withstand the load of train operation by four-car sets (2M2T) operated at six-minute intervals (morning peak commute hours) and, in the future, by eight-car sets (4M4T) operated at five-minute intervals (morning peak commute hours) and shall be capable of bearing the shared load of the adjacent Line 5 substation when it fails. Considering these factors, all seven Line 5 substations shall be equipped with two rectifiers each with capacity of 4.000 kW and two transformers (for rectifier 22 kV/1,180 V) each with capacity of 4,470 kVA.

The rectifiers shall be self-cooled heat-pipe type silicon rectifiers using pure water as coolant for environmental consideration.

3) DC feeding facilities

The DC feeding facility is a facility used to feed DC power produced by the DC transformer facilities to the contact wire system and consists of circuit breakers, disconnecting switches, arresters, instrumentation, etc.

The DC 1,500 V produced at seven Line 5 substations by the DC transformer facilities shall be supplied to four contact wire systems divided by lines and areas. The DC 1,500 V shall be supplied to the depot area from the Line 5 substation Line 5-(iii) via two private power lines.

Moreover, HSVCB (high speed vacuum circuit breaker) shall be used as a breaker for the DC power lines, which is arcless, compact, and free of exposed live parts, and ensures safe and almost sound-free break operation.

4) High voltage distribution facilities

The high voltage distribution facility is a facility used to supply AC power to the power distribution stations (explained later) and consists of transformers (for supplementary facilities 22 kV/6,600 V), circuit breakers, disconnecting switches, arresters, control equipment, instrumentation, etc.). The AC 22 kV (3 φ) received at Line 5 substations shall be stepped down to AC 6,600 V (3 φ) by the transformers (for supplementary facilities 22 kV/6,600 V) and AC 6,600 V (3 φ) is supplied to the distribution lines. Each distribution line shall consist of two lines considering possible power interruption and be configured as mutual standby system with the Line 5 substation with high voltage distribution facility as a counterpart (different system transmission scheme). The AC 6,600 V (3 φ) shall be supplied to the depot area from the Line 5 substation Line 5-(iii) via two private power lines.

Considering voltage drops due to distribution lines, high voltage distribution facilities shall be located at four Line 5 substations (Line 5-(i), Line 5-(iii), Line 5-(v), and Line 5-(vii)).

Considering loads at the distribution stations, two transformers (for supplementary facilities 22 kV/6,600 V) having capacity of 3,000 kVA each shall be installed at each four Line 5 substation (Line 5-(i), Line 5-(iii), Line 5-(v), and Line 5-(vii)).

In the case of the underground track plan in the downtown area, considering the increased load for air conditioning system, etc., at the distribution stations of five underground stations (St. 1 through St. 5), the capacity of two transformers (for supplementary facilities 22 kV/6,600 V) installed at the Line 5 substation Line 5-(i) shall be increased to 10,000 kVA each.

Table 3.6.4 shows combinations of facilities of the above 1) through 4), and Table 3.6.5 shows capacities of principal facilities at the substations in seven Line 5 substations.

Table 3.6.4 List of facilities installed at the Line 5 substations

Section	Line5 Substation	Receiving facilities	Transmission facilities	Direct current transformer facilities	DC feeding facilities	High voltage distribution facilities
Phase1	Line 5-(i)	●	●	●	●	●
	Line 5-(ii)		●	●	●	
	Line 5-(iii)	●	●	●	●	●
Phase2	Line 5-(iv)		●	●	●	
	Line 5-(v)		●	●	●	●
	Line 5-(vi)	●	●	●	●	
	Line 5-(vii)			●	●	●

Source: JICA Study Team

Table 3.6.5 List of capacities of principal facilities at the Line 5 substations

Section	Line5 Substation	Direct current transformer facilities						High voltage distribution facilities		
		rectifier			transformer (for rectifier)			transformer (for supplementary facilities)		
		Capacity (kW)	Unit	Total capacity (kW)	Capacity (kW)	Unit	Total capacity (kW)	Capacity (kW)	Unit	Total capacity (kW)
Phase1	Line 5-(i)	4,000	2	8,000	4,470	2	8,940	3,000	2	6,000
	Line 5-(ii)	4,000	2	8,000	4,470	2	8,940			
	Line 5-(iii)	4,000	2	8,000	4,470	2	8,940	3,000	2	6,000
	Subtotal		6	24,000		6	26,820		4	12,000
Phase2	Line 5-(iv)	4000	2	8,000	4,470	2	8,940			
	Line 5-(v)	4000	2	8,000	4,470	2	8,940	3,000	2	6,000
	Line 5-(vi)	4000	2	8,000	4,470	2	8,940			
	Line 5-(vii)	4,000	2	8,000	4,470	2	8,940	3,000	2	6,000
	Subtotal		8	32,000		8	35,760		4	12,000
Total			14	56,000		14	62,580		8	24,000

Source: JICA Study Team

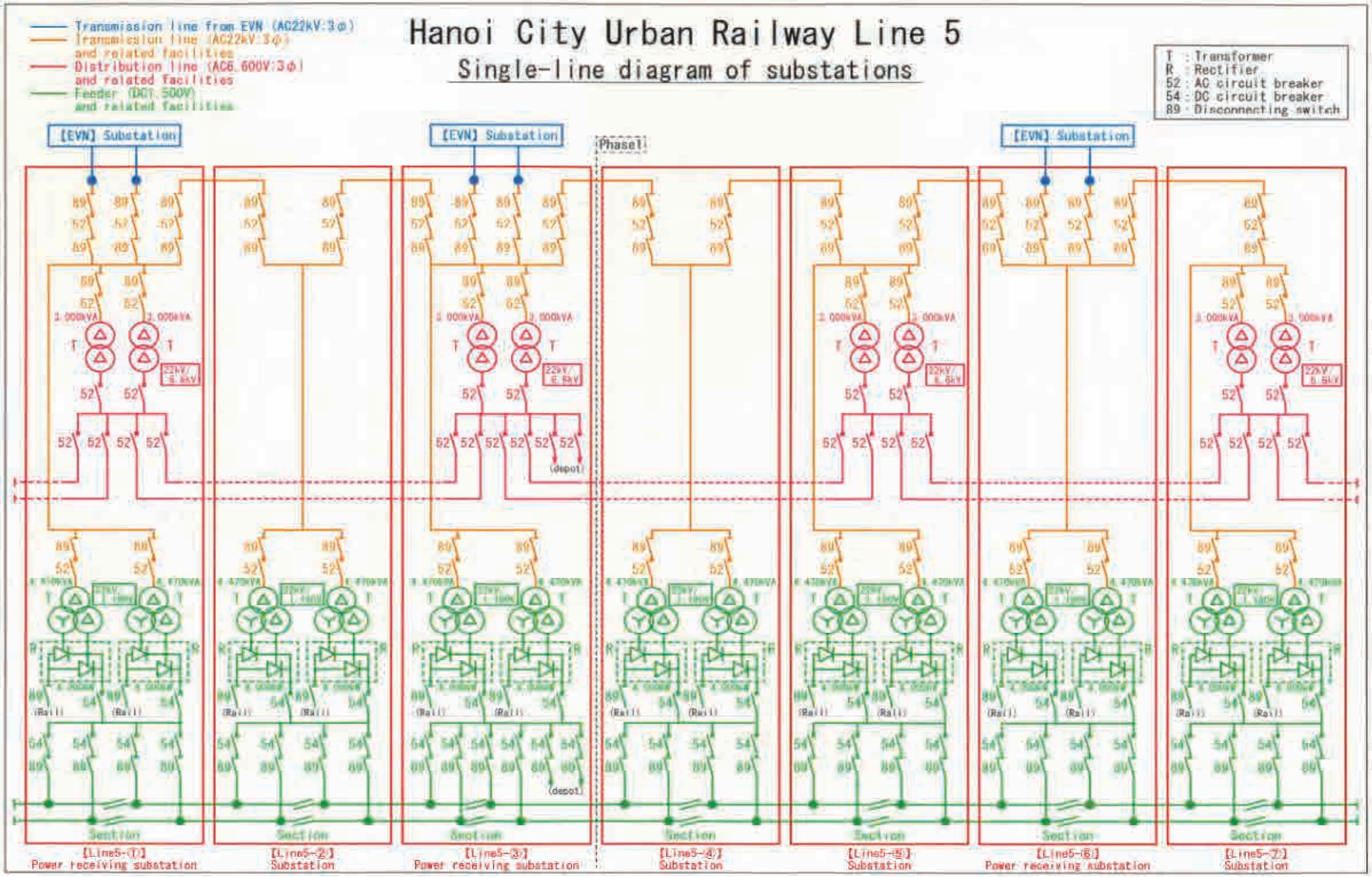


Figure 3.6.4 Single-line diagram of the Line 5 substations

Source: JICA Study Team

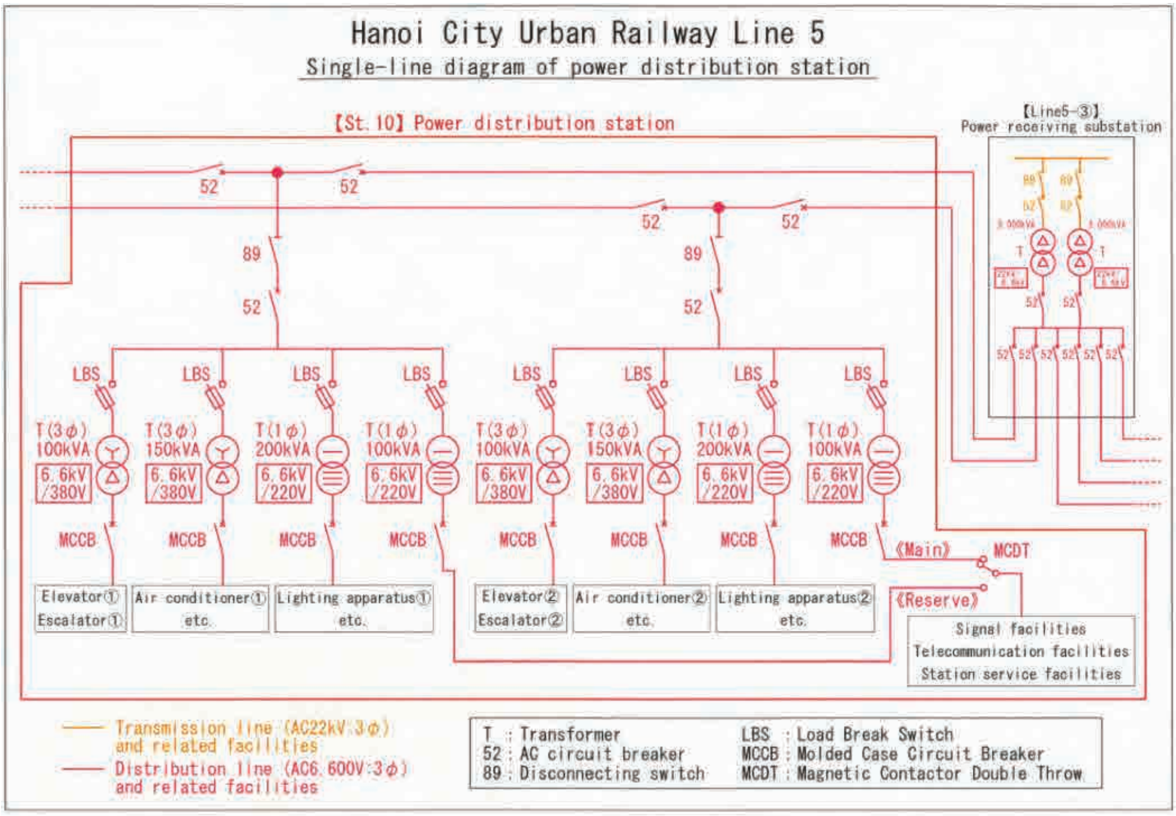
(5) Other facilities and equipment

1) Power distribution station (see Figure 3.6.5)

The power distribution station (PDS) is a facility supplying power to the electrical facilities of the station (elevators, escalators, air conditioning system, lighting system, etc.), signaling system, communication system, AFC devices, etc., and seventeen distribution stations at the stations (from St. 1 to St. 17) and two distribution stations at the depot (central command post and workshop) shall be installed.

Electrical power to the power distribution station is supplied from the adjacent Line 5 substation via two distribution lines (AC 6,600 V, 3 φ) in order to enhance reliability. The AC 6,600 V, 3 φ received shall be stepped down to AC 380 V by the transformer (3 φ, 6,600/380 V) to supply electricity for elevators, escalators, air conditioning system, plumbing system, and also stepped down to AC 220 V by the transformer (1 φ, 6,600/220 V) for the lighting system, signaling system, communication system, AFC devices, etc.

The load of each facility shall be shared by two distribution lines to prevent complete shutdown of the elevator, escalator, air conditioning system and lighting system, etc., even when one distribution line is interrupted. With respect to power supply to the signaling system, communication system, and AFC devices, the normal and stand-by systems shall be combined as an interlocking system that allows uninterrupted switching to enhance reliability. In addition, emergency power generating equipment shall be installed at the power distribution station of the central command post (CCP). Circuit breakers, disconnecting switches, switching stations, arresters, instrumentation, etc., suitable for the use shall be installed.

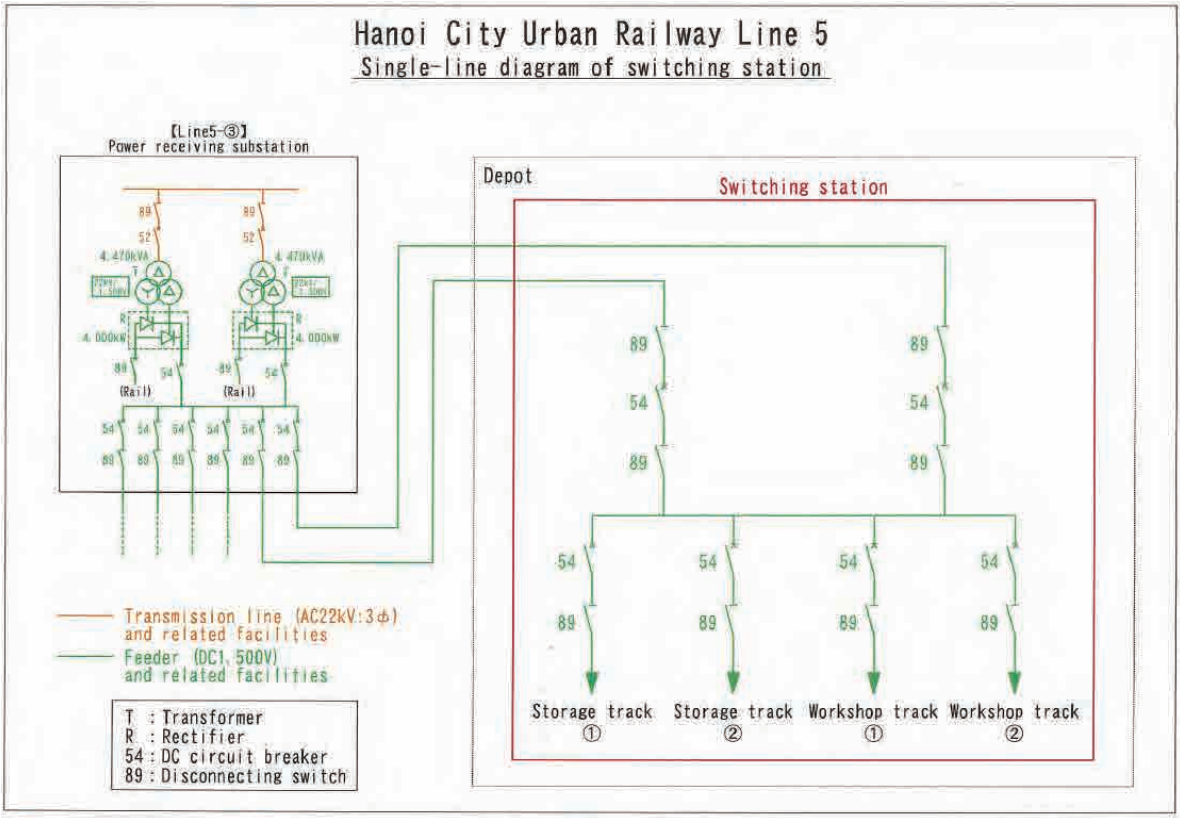


Source: JICA Study Team

Figure 3.6.5 Single-line diagram of power distribution station (Example: St.10)

2) Switching station (Figure 3.6.6)

The switching station shall be installed in the depot, to separate the electric power (DC 1,500 V) between the side track of the Line 5 and the depot. Electric power is distributed to the respective areas within the depot via circuit breakers and disconnecting switches in the switching station. Circuit breakers and disconnecting switches for the side track, and arresters, instrumentation, etc., suitable for the use shall be also installed.



Source: JICA Study Team

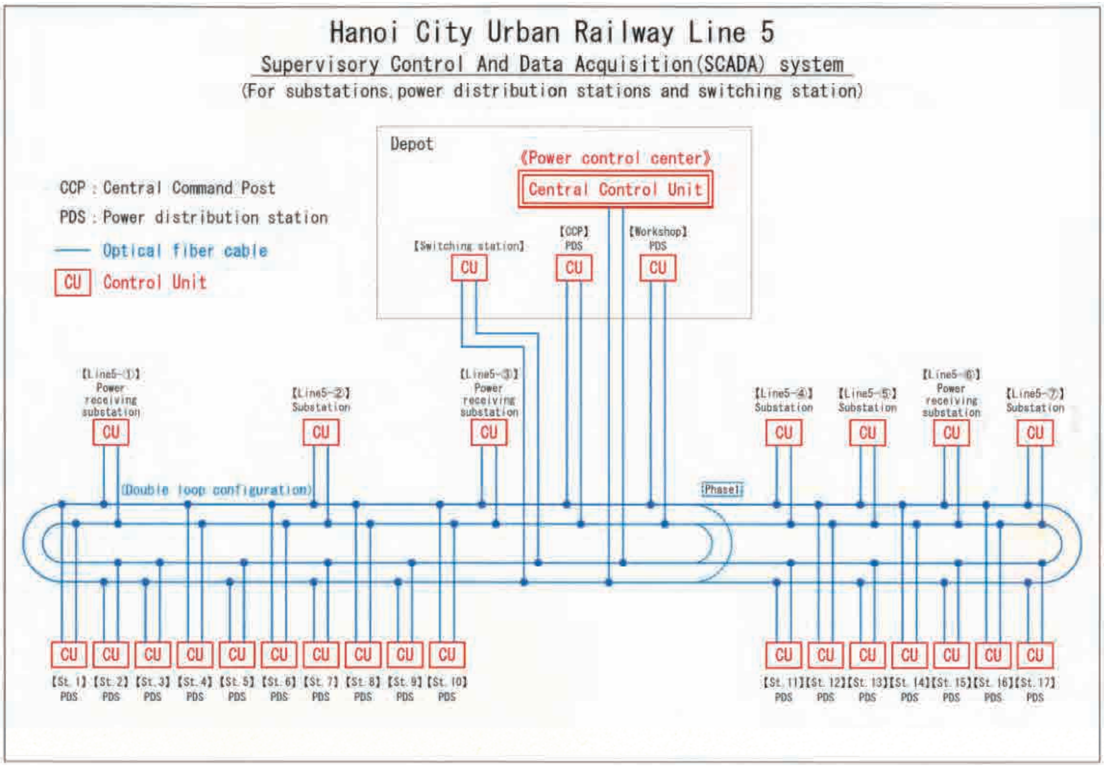
Figure 3.6.6 Single-line diagram of switching station

3) Supervisory control and data acquisition system of the substation (see Figure 3.6.7)

The SCADA (supervisory control and data acquisition) system of the substation is a system to monitor and control the substations (at seven locations), power distribution stations (at 19 locations), and switching stations remotely from the power command center (see Figure 3.6.8).

The system shall have a loop configuration (dual loop) where the CCU (central control unit) at the power command center and the control units located at the substations, distribution stations, and switching stations are connected by optical fiber cables. With such configuration, adverse effect on control and monitoring will be minimized even when interruption of the optical fiber cable takes place, since alternative route is established.

With respect to the monitoring and control of the substations, distribution stations, and switching stations, restoration of the fault is provided automatically or by proposal control scheme based on the information on operating status of the equipment, fault status displayed, and measured voltage and current. The system also has functions of automatic operation, shut down, and scheduled power interruption and transmission for maintenance work at night.



Source: JICA Study Team

Figure 3.6.7 SCADA (supervisory control and data acquisition) system

Source: JICA Study Team

Figure3.6.8 An appearance of Power control center

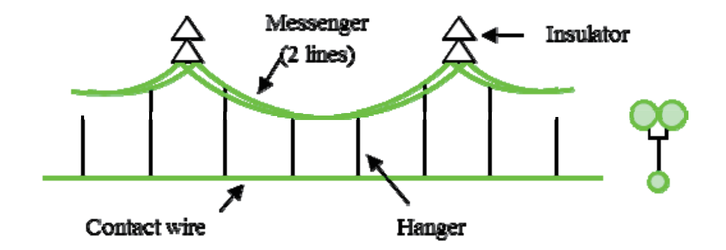
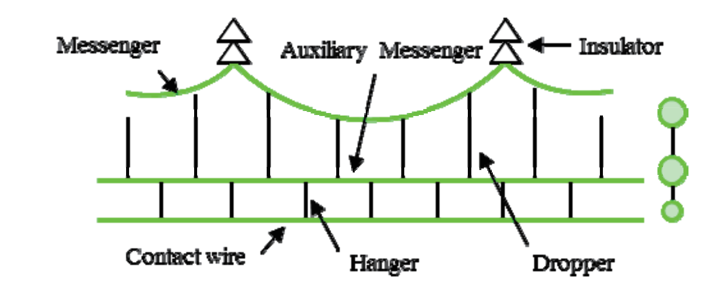
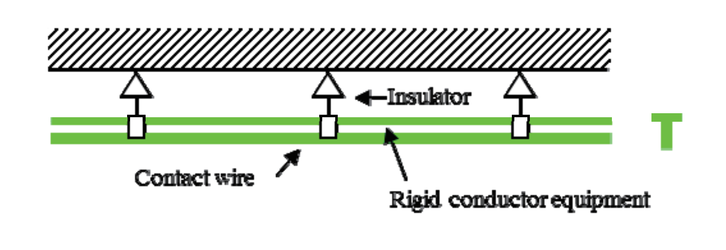
3.6.2 Plan of contact wire system

(1) Contact wire system

The contact wire system is a facility to supply DC power (DC 1,500 V) fed by the Line 5 substations to trains via power collectors (pantographs). A single overhead contact wire shall be used as a construction method for the Line 5 in accordance with the Urban Railway Standards of Vietnam, and height of the contact wire measured from the top of the rail shall be 5.0 m (4.4 m or more) according to the Annex to the Technical Standards of Vietnam. Typical overhead contact wire schemes in the single overhead contact wire are as shown in Table 3.6.6. For the overhead contact wire system used in the Line 5, simple catenary system in Table 3.6.6 shall be used considering the maximum operating speed of 120 km/h (design maximum speed: 130 km/h).

In order to reduce maintenance costs, feeder messenger system where number of wires is large but number of components required is small combining feeder line and messenger wire shall be used as the simple catenary equipment. The overhead contact wire system consists of feeder messenger wire, contact wire, hangers, insulators, etc., and dual feeder messenger wires shall be used considering electrical capacity. In the underground section of the underground track plan in the midtown area (maximum operating speed: 90 km/h), overhead rigid conductor equipment shall be used.

Table 3.6.6 Typical overhead contact wire systems

Simple catenary equipment		
Applied speed performance	130km/h or less	
Applicable section	Elevated, Ground (Underground)	
Compound catenary equipment		
Applied speed performance	160km/h or less	
Applicable section	Elevated, Ground (Underground)	
Overhead rigid conductor equipment		
Applied speed performance	90km/h or less	
Applicable section	Underground	

Source: JICA Study Team

Auxiliary equipment, such as the automatic tensioner (see Figure 3.6.9) that maintains tension of the contact wire and feeder messenger wire constant against expansion or contraction under varying temperature, shall be also installed.

Source: JICA Study Team

Figure 3.6.9 Image of automatic tensioner

(2) Distribution line system

The distribution line system is a system used to supply electricity (AC 6,600 V) produced by the Line 5 substations equipped with the high voltage distribution facilities to the distribution stations. Two lines of distribution line (AC 6,600 V, 3 φ power cable) shall be installed in the concrete troughs along entire tracks between St. 1 and St. 17 and between Line 5 substation Line 5(iii) and the depot.

(3) Transmission line system

The transmission line system is a system used to supply electricity (AC 22 kV) produced by the Line 5 substations connected to EVN substations to the Line 5 substations that are not connected to EVN substation via private transmission lines. Transmission lines (AC 22 kV, 3 φ power cable) shall be installed in the concrete troughs along the entire tracks between Line 5 substations Line 5-(i) through Line 5-(vii).

(4) Other wires and cables

The Urban Railway Standards of Vietnam specifies that the train radio system shall use LCX (leaky coaxial cable), which shall be installed along the sidewalls at both sides of the tracks. Optical fiber cables, signal cables, communication cables, etc., shall be installed in the concrete troughs located at track side.

(5) Support

The support consists of equipment to support the contact wire system and other auxiliary equipment. On the Line 5, steel pipe columns shall be used for scenic and seismic consideration.

Schematic diagram of the electrical circuit systems (1) through (5) above is shown in Figure 3.6.10.

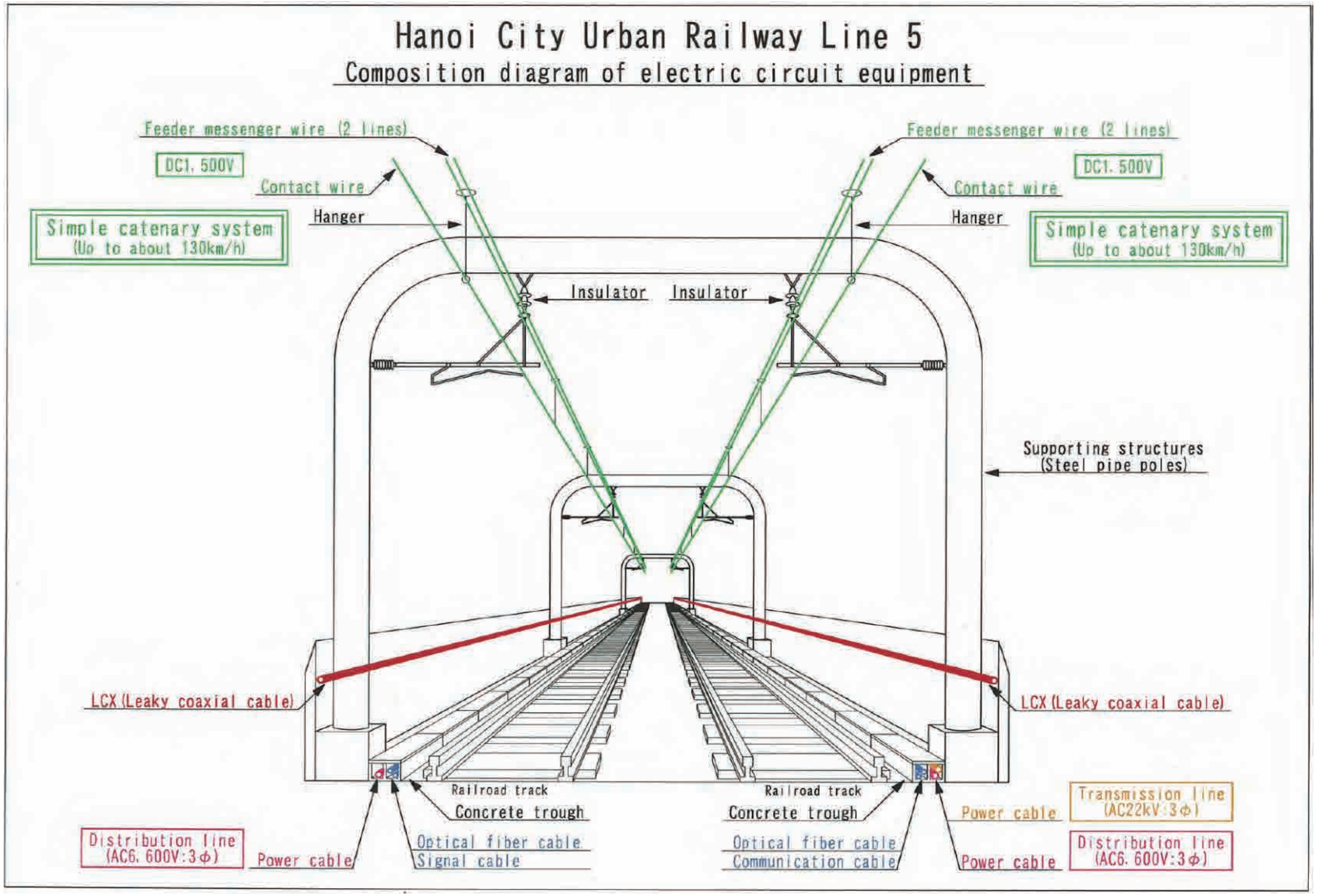


Figure 3.6.10 Composition diagram of electric circuit equipment Source: JICA Study Team

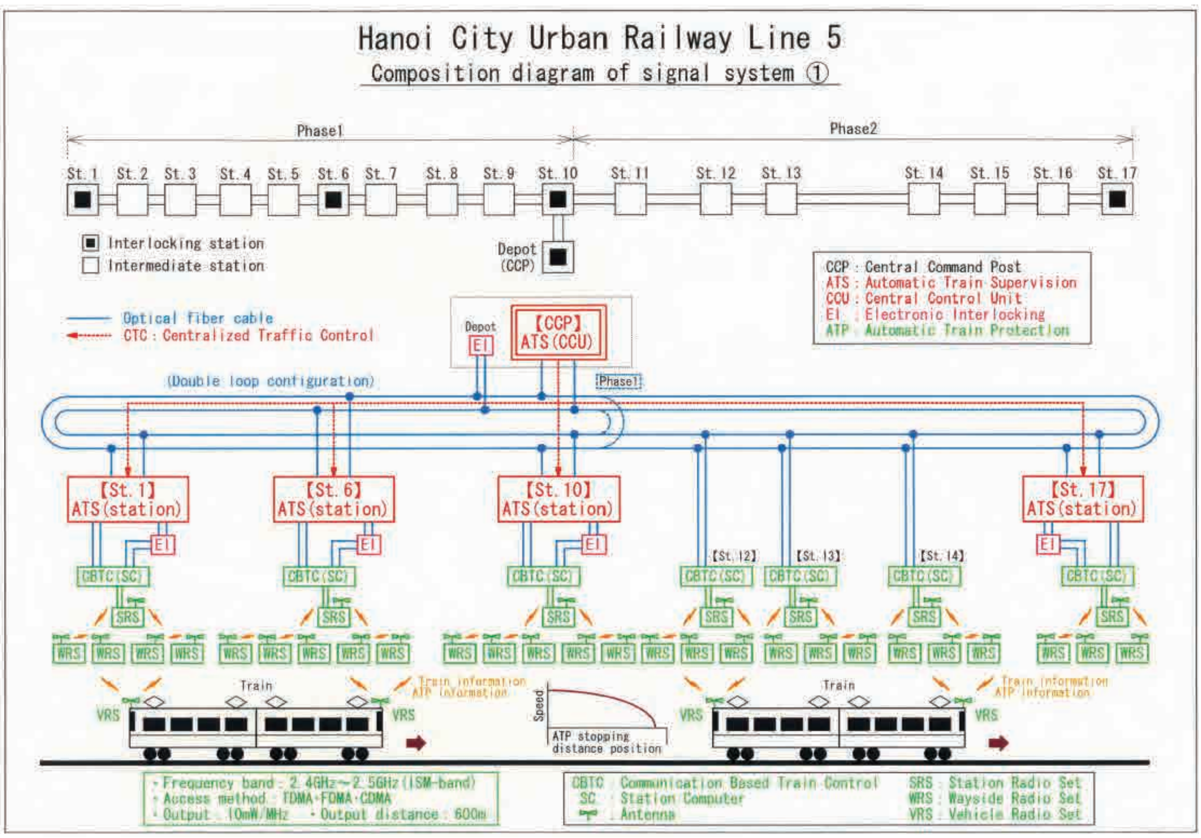
3.7 Signaling and Communication facilities

3.7.1 Plan of signaling facilities

(1) Outline of the signaling system (see Figures 3.7.1 and 3.7.2)

On the Line 5, 17 stations and one depot shall be located, and a total of four stations (St. 1, St. 6, St. 10, and St. 17), except the depot, are planned as interlocking stations.

The signaling system proposed for the Line 5 has enhanced safety and reliability consisting of "CBTC (Communication Based Train Control) system (a system that establishes blocks and detects the train location)", "ATP (automatic train protection) system (a system that establishes distance between trains and automatically decelerates and stops trains)", "ATO (automatic train operation) system (a system that allows automatic operation of trains)", "ATS (automatic train supervision) system", "EI (electronic interlocking) devices" incorporating fail-safe functions to operate the system safely in case of a power failure or malfunction, and a duplex configuration for backup. The system configuration shall also consider ease of maintenance and the ability to augment for extension of the line and installation of new stations in the future.



Source: JICA Study Team

Figure 3.7.1 Composition diagram of signaling system (1)

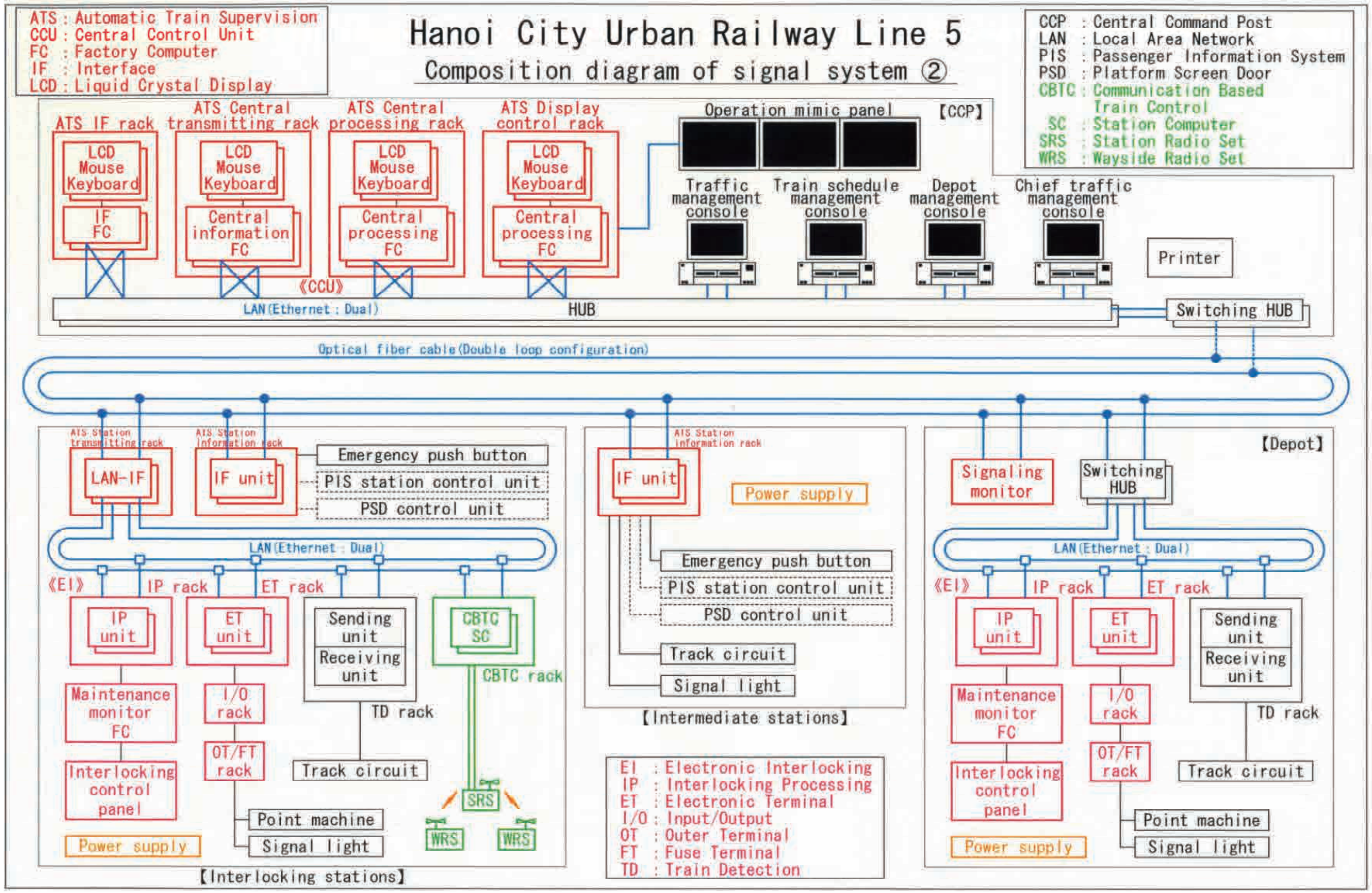


Figure 3.7.2 Composition diagram of signaling system (2)

Source: JICA Study Team

(2) CBTC system

For the Line 5, the CBTC (communication-based train control) system is proposed because it is the international standard for urban railway systems, superior in cost effectiveness, and flexible in construction and modification of the system compared with a conventional track circuit system as the main system to establish blocks and detect train locations, which will be also introduced in other rail lines in Vietnam.

Matters studied and investigated in the study for proposal of the CBTC system are as follows.

1) Outline of the CBTC system

According to the international standard IEEE (Institute of Electrical and Electronics Engineers) 1474, the CBTC system is an automatic train control system utilizing high-resolution train location determination independent of track circuits capable of high-capacity, bidirectional train-to-wayside data communications. Communication in the CBTC system generally means wireless communication, and when it is specifically referred to as the wireless CBTC system, it generally means the space-wave method with antennas at wayside (ground) radio sets. Because train locations can be determined in high resolution, the moving block system is used in most CBTC systems.

The CBTC system is far superior to the fixed block (track circuit) system that had been used in urban railway systems in Japan for a long time with respect to the equipment required, ease of maintenance, operating efficiency, and accuracy in locating trains.

Additionally, safety and reliability of train control using wireless technology have been proven through operation tests based on technology developed by the Railway Technical Research Institute in Japan. In recent years, introduction examples of CBTC system installations by Japanese companies are reported in a few countries. Use of the CBTC system is also being considered for Line 2 and Line 3 in Hanoi and Line 1 in Ho Chi Minh City.

2) CBTC system proposed for the Line 5 (see Figure 3.7.3)

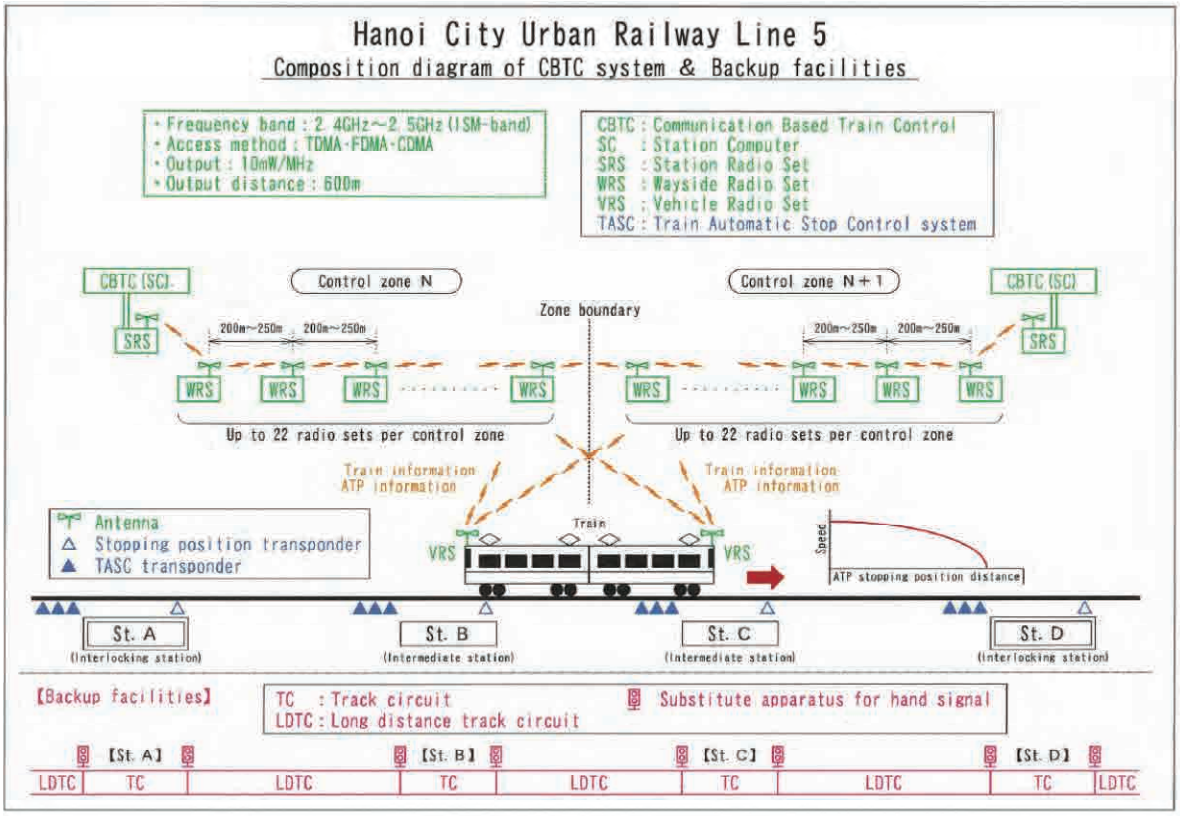
(i) System configuration

The station computers (SC) continuously exchange location data (ATP information) and vehicle data (vehicle information) with the trains (vehicle onboard equipment) via station radio sets (SRS), wayside radio sets (WRS), and vehicle radio sets (VRS).

The station computers (SC) will be installed at the interlocking stations (St. 1, St. 6, St. 10, and St. 17) with the control zone of each unit as about three to five kilometers. The relaying station computer (SC) will be also installed in the sections where distance between interlocking stations (from St. 11 to St. 17) is large. The wayside radio sets (WRS) can be installed at a maximum of 22 units for each control zone, and they will be installed at an interval of about 200 to 250 meters taking visibility of the train driver and the wayside structures into account.

In the underground track plan in the midtown areas, the number of wayside radio sets (WRS) will increase, but the system configuration is the same as that of the elevated and ground level track sections.

Because the database is maintained in the SC in the CBTC system proposed for the Line 5, modification of the data maintained in the SC only is required when it becomes necessary due to line extension or addition of stations in the future without requiring modification of the data on the onboard computer. The train detecting function, ATP function, and ATO function are integrated in the CBTC system, which allows for a reduction in the equipment and ease of maintenance.



Source: JICA Study Team

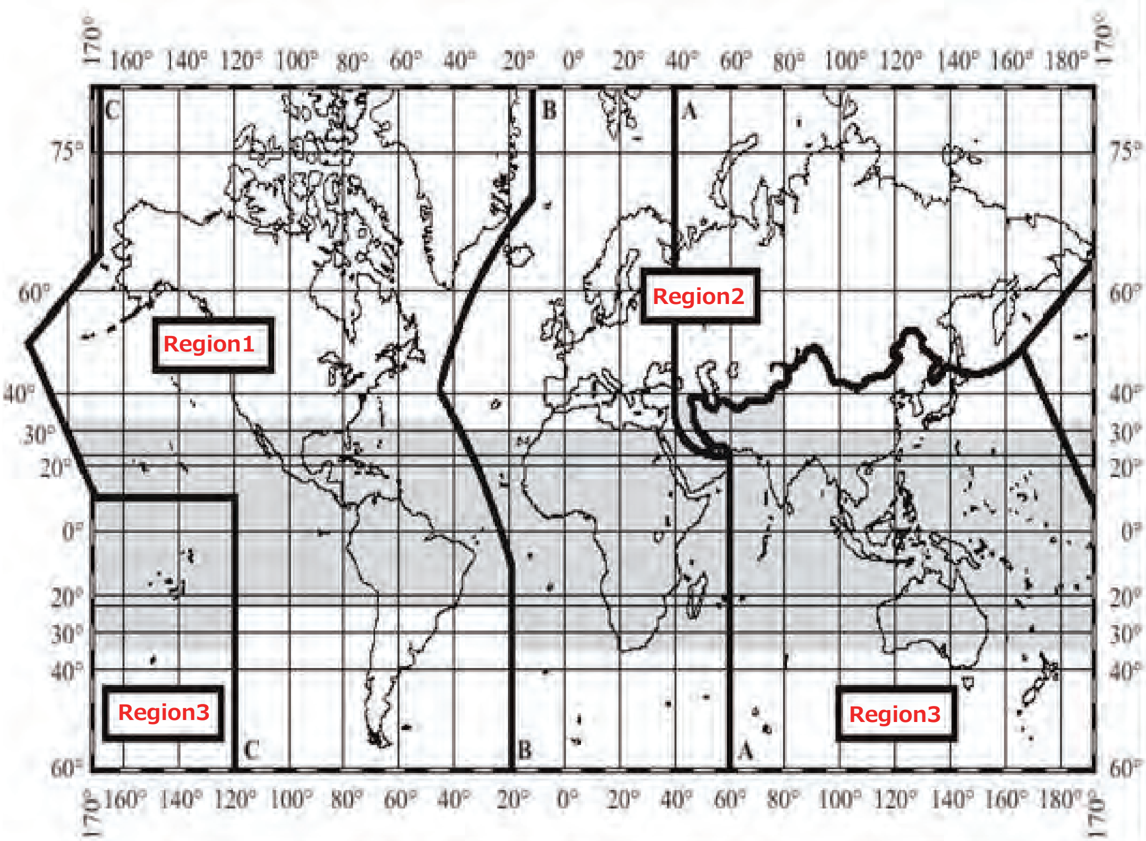
Figure 3.7.3 Composition diagram of CBTC system and back-up facilities

(ii) Train position detection method

Train positions are detected by two systems to enhance safety and reliability, consisting of a combination of transponders for TASC (train automatic stopping controller) installed along the track for compensation of location and the tacho-generator (TG) and the wireless ranging system, which calculates train location by the communication time between the WRS and VRS.

(iii) Radio frequency

Vietnam is a signatory of the ITU Treaty and belongs to Region 3 like Japan. The 2.4 to 2.5 GHz frequency band for general purposes was considered for use in CBTC wireless data communication proposed for the Line 5; however, when Study Team contacted the Radio Frequency Directorate (RFD) of the Ministry of Information and Communications (MIC) to confirm the frequency band for the system on the Line 5, their response was the ISM (industry science medical) frequency band. In the design phase of the Line 5 construction project after its approval, a letter for the frequency band of the system and permission for radio equipment operation will be submitted, and technical compliance checks will be made of the radio sets, cables, and antennas.



Source: 125/2009/QĐ-TTg

Figure 3.7.4 Region assignment made by the International Telecommunication Union (ITU)

(iv) Anti-interference measures of wireless communication

Because the ISM frequency band shall be used that does not require an operating license and operates with low-power radio sets, the combination of TDMA, FDMA, and CDMA is used as the access method.

■ TDMA (Time Division Multiple Access)

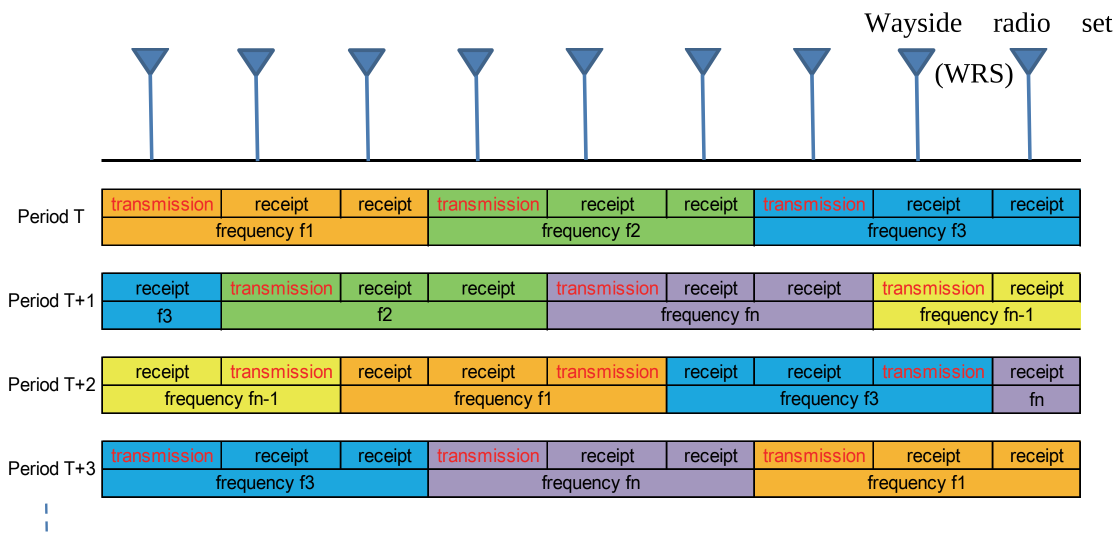
Real time communication is used to avoid data collisions by assignment of unique time slots for the respective trains by the WRSs.

■ FDMA (Frequency Division Multiple Access)

As shown in Figure 3.7.5, the WRSs operate the switching frequency at a constant interval and even if a certain frequency is obstructed, data communication continues on a different frequency in the next cycle, which makes complete obstruction of communications very unlikely.

■ CDMA (Code Division Multiple Access)

Encryption of the data communication is applied to prevent interception, alteration, and/or ID forgery by third parties in wireless communication.



Source: JICA Study Team

Figure 3.7.5 Conceptual diagram of frequency switching

(v) Backup facility of the CBTC system

The CBTC system does not allow detection of rail failures or detection of train locations if the system is not operational. Although it will increase the facility costs, a system consisting of the track circuit and substitute apparatus for hand signals is proposed to enhance safety and operational robustness as the backup to the CBTC system on the Line 5.

The track circuit facility, when installed, will allow detection of rail failures or detection of train positions if the CBTC system becomes non-operational. It is also possible to continue train operation using a substitute apparatus for hand signals if the CBTC system is non-operational.

Table 3.7.1 shows the comparison between the CBTC system only and the CBTC system plus an installed backup facility.

Table 3.7.1 Comparison of Backup Facility to the CBTC System Studied

Item		CBTC System and Backup Facility	CBTC System
Safety (Fail safe)		◎	◎
Costs	Initial	△	○
	Running	△	○
	Renewal	△	○
Maintainability/number of equipment		○	◎
Operating efficiency, availability		◎	○
Accuracy in position detections		◎	○
Rail breakage detection		◎	×
Overall Rating		**◎**	**○**

As backup facility of the CBCT system, track circuits are planned to be installed; that is, 73 sets in station premises and 52 sets between stations.

《Legend》 ◎: Excellent ○: Good △: Poor ×: Bad

Source: JICA Study Team

With respect to the depot, control shall be made by the track circuit system and shunting signals instead of CBTC system. Accordingly, as the system that establishes blocks and detects trains etc. in Line 5, systems shown in Table 3.7.2 are proposed.

Table 3.7.2 System configuration establishing blocks and detecting train location

Item	System establishing blocks and detecting train position	
	Primary control	Backup system
Main Line	CBTC system	Track circuit system and Substitute apparatus for hand signal
Depot	Track circuit system and shunting signal	

Source: JICA Study Team

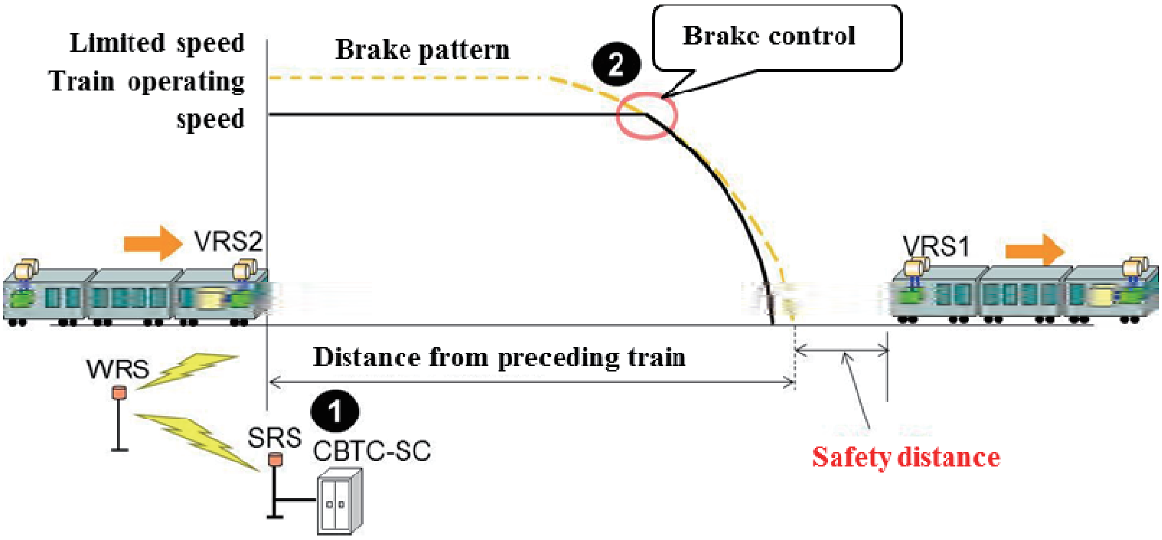
(3) ATP (Automatic Train Protection) system

On the Line 5, the ATP (automatic train protection) system shall be installed as a system that establishes the distance between trains and automatically decelerates or stops trains. As the ATP system, the ATC (automatic train control) system is introduced in compliance with the Urban Railway Standards of Vietnam. The ATC system automatically decelerates or stops the train by continuous control depending on the distance between trains on the track and conditions of the track.

The ATP (ATC) system shall be integrated with the CBTC system to reduce the equipment and improve maintainability. As Figure 3.7.6 shows, the station computer (SC) of the CBTC system continuously transmits distance information from the preceding train (ATP information) via station radio sets (SRS), wayside radio sets (WRS), and vehicle radio sets (VRS). The onboard computer of the train constantly creates a braking pattern (signal speed) based on the distance information (ATP information) to the preceding train.

When speed of the train exceeds the braking pattern (speed signal pattern) created by the onboard computer, the service braking system is automatically activated to decelerate the train to the speed signal pattern or stop the train. The service brake will be deactivated when the train speed is reduced to the braking pattern (speed signal pattern) or below.

Moreover, in case the train is not able to receive information from the station computer (SC) for a definite period of time, fail safe system is planned to activate emergency brake.



Source: JICA Study Team

Figure 3.7.6 Train protecting method

(4) ATO (Automatic Train Operation) system

On the Line 5, the ATO (automatic train operation) system shall be installed as a system that allows automatic operation of trains in compliance with the Urban Railway Standards of Vietnam because PSDs (platform screen door) will be installed in all stations.

The ATO system shall be integrated with the CBTC system to reduce the equipment and improve maintainability. When operating mode of the train is switched to the ATO mode of operation, control for acceleration, coasting, deceleration, and stop at a fixed position is automatically provided according to the braking pattern (speed signal pattern) created based on the location data (ATP information) transmitted from the CBTC system.

The onboard ATO system determines the exact train location by detecting the transponders for TASC installed on the track and executes the TASC (train automatic stop control) operation to stop the train at the stop point transponder. After the train automatically stops at the fixed stop point, communication is established between the onboard and station ATO systems and the platform screen doors (PSDs) and vehicle doors are operated.

(5) ATS (Automatic Train Supervision) system

In order to allow precise, expedient, comfortable, and safe control of train operation, the ATS (automatic train supervision) system shall be installed. The ATS system shall be the centralized traffic control (CTC) system in compliance with the Urban Railway Standards of Vietnam and will provide centralized management and control of train operation at the Central Command Post (CCP). (See Figure 3.7.7)

During normal operation, control of tracks at each interlocking station (St. 1, St. 6, St. 10, and St. 17) is made remotely from the central control unit (CCU) located at the CCP.

The system configuration shall allow manual remote control from the CCP or manual control at each interlocking station (St. 1, St. 6, St. 10, and St. 17) in the case of trouble. The system shall have diagnostic and troubleshooting functions.

With respect to control of tracks within the depot, automatic or manual control shall be provided by the Depot management console located in the CCP.

The system shall have loop configuration (dual loop) where the CCU at the CCP and the station control units located at the interlocking stations (St. 1, St. 6, St. 10, and St. 17) are connected with the optical fiber cables. With such configuration, adverse effect on control and monitoring will be minimized even when interruption of the optical fiber cable takes place, since alternative route is established.

The ATS system shall have a simple configuration considering ease of operation and maintenance while establishing high speed processing capability and high reliability, and the operation mimic panel and the monitor displays shall take visibility, operability, and maintainability in consideration.

The principal units of the ATS system are as follows.

1) Operation mimic panel

The operation mimic panel allows monitoring of train operation in entire Line 5 with location of the train, train number, signals, etc. displayed.

2) ATS central processing rack

The ATS central processing rack provides automatic control of tracks for trains according to the operation diagram tracking movement of the trains. The system also monitors arrival and departure status of the trains at stations, and if delay from the diagram is detected, appropriate processing is initiated.

3) ATS central transmitting rack

The ATS central transmitting rack distributes control information from the CCP via ATS central processing rack and the traffic management console to the stations and collects display information from the stations. The ATS central transmitting rack also saves control information and provides automatic restoration of the control.

4) ATS station transmitting rack

The ATS station transmitting rack receives control information from the CCP and transmits the information to interlocking system etc. The ATS station transmitting rack also receives display information from the interlocking system and transmits it to the CCP.

5) Traffic management console

The traffic management console allows monitoring of train operation in entire Line 5 and manual operation of signaling and controls, and it allows correction of the operation diagram.

The traffic management console also assists the controllers in taking appropriate action and processing by raising an alarm in the event of a problem in the automatic control system due to a delay in train operation or when trouble with the equipment is detected.

6) Train schedule management console

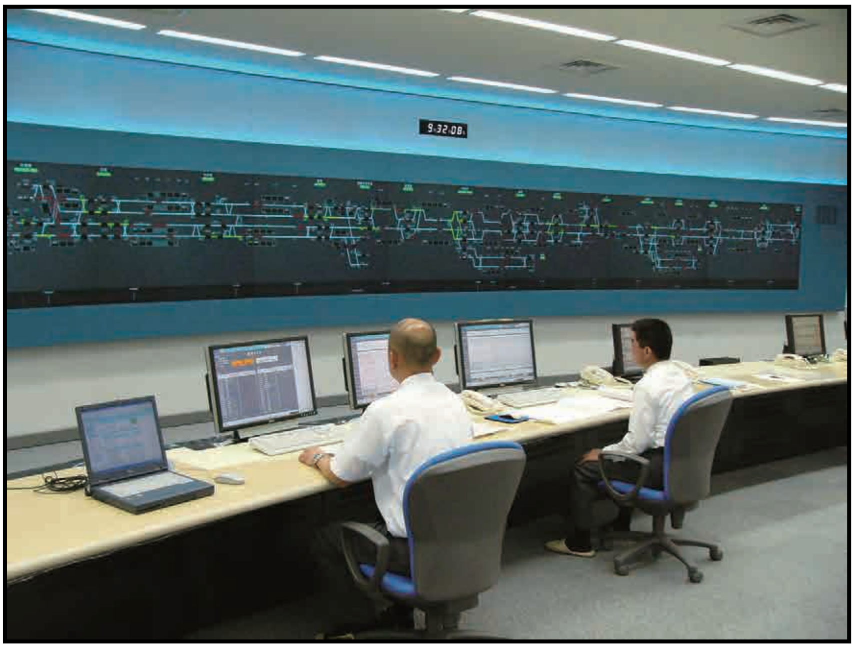
The train schedule management console allows preparation and management of the planned and specific train operation diagram and then manages and saves the actual operation schedule. The console also serves a part of the traffic management console functions such as display of train operation status and manual control.

7) Depot management console

The depot management console provides management of operation schedule, train tracking, automatic control of tracks within the depot. The console also allows monitoring of train operation within the depot, manual operation of the signal control and the preparation and correction of the operation schedule within the depot.

8) Signal monitor

The signal monitor monitors operation status of the systems in the CCP and of facilities at stations and displays and records faults of the systems.



Source: JICA Study Team

Figure 3.7.7 Central command post

(6) Interlocking device

Electronic Interlocking (EI) is proposed as the interlocking device, which has become common nowadays. The EI allows high-speed processing and is superior in reliability and maintainability. Safety shall be established by fail-safe scheme and high reliability of the principal systems shall be established by duplex system configuration. Appropriate action and instruction shall be provided by the self-diagnostic function to avoid complete system failure. The EI system shall be installed at the interlocking stations (St. 1, St. 6, St. 10, and St. 17) and the depot, total five locations.

The principal units of the EI system are as follows.

1) Interlocking Processing (IP) rack

Route control of tracks is made safely and securely locking the signals and switches using fail-safe schemes with interlocking logics constructed by the software of the IP unit in the IP rack. This unit has high-speed processing capability to handle large number of trains in operation. The unit also has fault detection and self-diagnostic functions. If interlocking logics need to be changed due to the reason such as the change in alignment at the station in the future, it can be easily made using the ladder wiring diagram modification tool.

2) ET (Electronic Terminal) rack

Control of the field equipment such as signals and switches is made by the ET (Electronic Terminal) unit in the ET rack according to the control information received from the IP unit. It also has a function to monitor the status of the field equipment.

3) Interlocking control panel

The computer display is used to display status of the signals, switches, train presence on the track, etc., in a highly visible manner by the interlocking control panel. This can be easily operated using a mouse and a keyboard.

4) Maintenance monitor

Status of the systems can be monitored by the maintenance monitor, and in case of system failure, the location of the failure can be identified. This monitor can save a record of the interlocking processing and operations and allows failure analysis if a failure occurs.

5) Input/Output (I/O) rack and Outer Terminal/ Fuse Terminal (OT/FT) rack

The Input/Output (I/O) rack and Outer Terminal/ Fuse Terminal (OT/FT) rack provide interface with the external systems and input from the power supply. The racks also provide protection of the system in the signaling equipment room from lightning surge and noise.

3.7.2 Plan of communication facilities

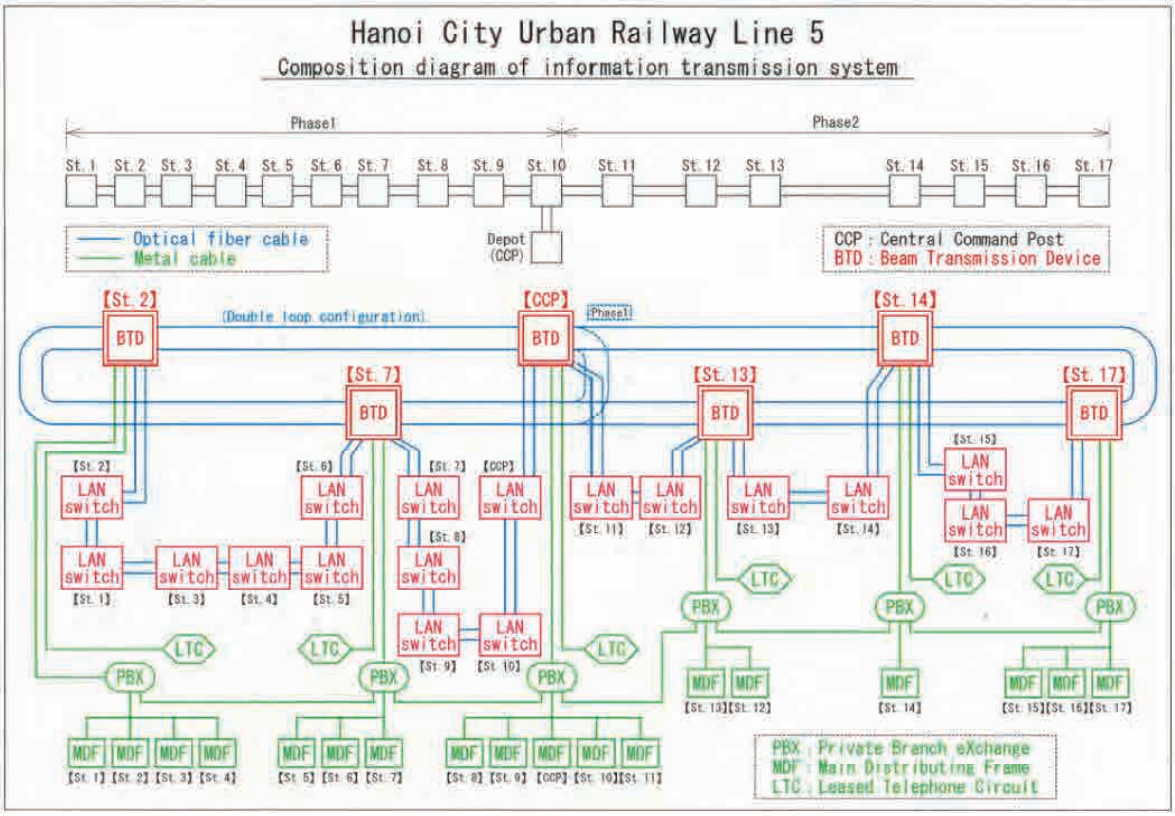
(1) Outline of the communication system

Communication system proposed for the Line 5 shall have safety, reliability, usability, serviceability and consist of the information transmission system, train radio system, image monitoring system, and passenger information system in order to provide effective support for control and operation of trains and to provide user friendly services to the passengers.

(2) Information transmission system (see Figure 3.7.8)

The information transmission system shall consist of six beam transmission devices (BTDs) installed at the communication equipment rooms at St. 2, St. 7, St. 13, St. 14, St. 17, and CCP) interconnected in loop (dual loop) configuration with the optical fiber cables. Such configuration allows uninterrupted information transmission by switching to the other line even when one optical fiber cable is broken. The BTD shall have multiple transmission capabilities for the time division multiplexing band to transmit voice signals and interlocking digital signals and for the packet multiplexing band to transmit IP data etc.

Efficient and economical operation of the telephone system shall be established by connecting private branch exchange (PBX) for private telephone networks and direct lines for direct telephones with the BTD and optical transmission. LAN switches that constitute the IP network of the automatic fare collection (AFC) devices and image monitoring system are also installed at each station using dual-loop connection of optical fiber cables and connected with the BTD. The main distributing frame (MDF) shall be installed at each station, which is connected via communication cables (metal cable) for private telephone networks and direct telephones.



Source: JICA Study Team

Figure 3.7.8 Composition diagram of information transmission system

(3) Train radio facilities (see Figure 3.7.9)

The LCX (leaky coaxial cable) duplex operation train radio system that allows direct communication between the CCP (central command post) and the train shall be installed in accordance with the Urban Railway Standards of Vietnam.

Two lines of LCX shall be installed along each track throughout the line in order to attain high transmission quality. 11 base stations need to be installed along the line with decay of the signal due to LCX considered, and the master station shall be installed at the CCP and slave stations shall be installed at St. 2, St. 5, St. 7, St. 9, St. 10, St. 12, St.13, St.14, St.16 and St. 17 respectively. The repeaters shall be installed in the sections where distance between the base stations is large (St.10-St.12 and St. 13-St. 14).

Digital train radio facilities consisting of central processing rack, traffic management console, base station equipment, vehicle station equipment, repeater, etc., are proposed for the Line 5 that has features such as clear voice communication, 4-channel narrow band operation, and data communication in addition to voice communication.

Specific functions as shown in Table 3.7.3 shall be allocated to four channels mentioned above. For convenience in operation, CCP voice communication channel (CH1) shall be divided into three zones consisting of Zone 1 (St. 1-St. 10), Zone 2 (St. 10-Depot), and Zone 3 (St. 10-St. 17) and independent communication in each zone shall be allowed. Zones shall be established for respective base stations with regard to the maintenance channel (CH2), protection channel (CH3), and data channel (CH4).

Table 3.7.3 Function of Each Channel

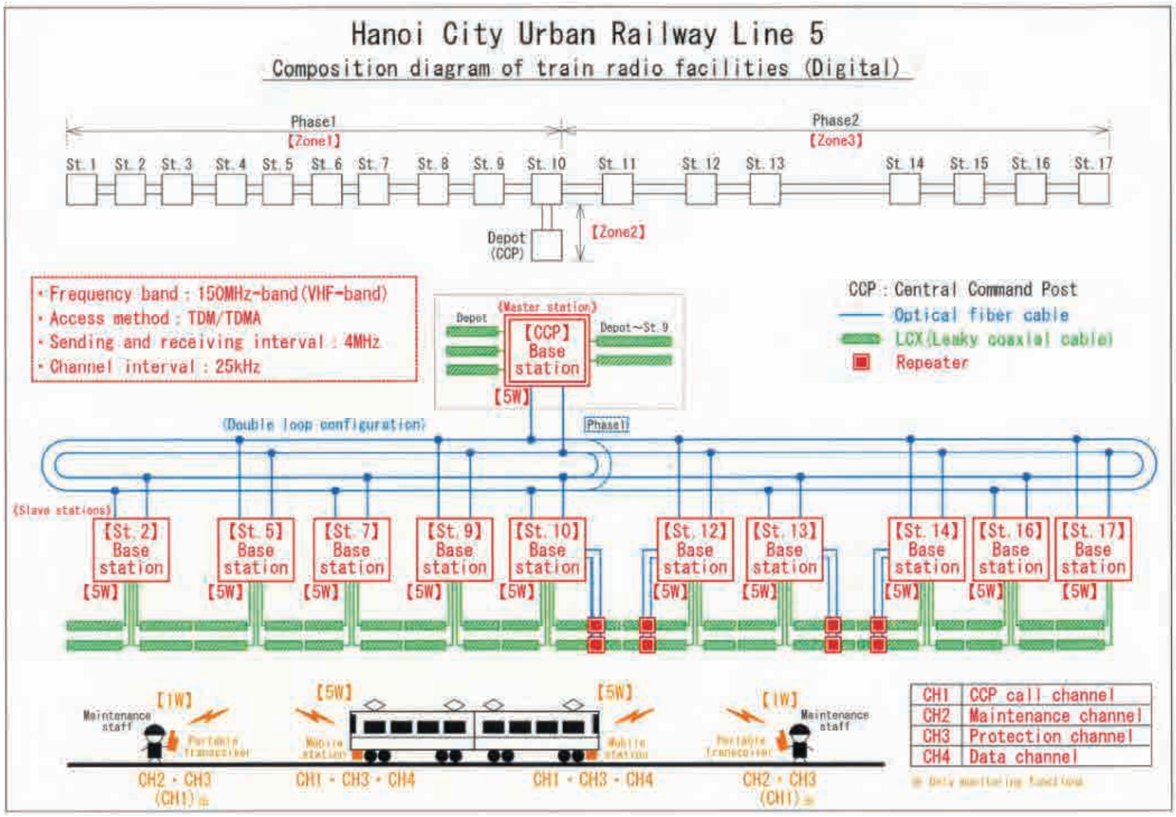
CH	Channel designation	Function and Operation
CH1	CCP voice communication channel	Principally used for voice communication between the commander and the train driver
CH2	Maintenance channel	Principally used for voice communication between the rain driver and the maintenance personnel
CH3	Protection channel	Principally used to transmit protection signal and acknowledgment of receipt
CH4	Data channel	Used for data communication such as train information

Source: JICA Study Team

The portable transceivers carried by the maintenance personnel and train drivers shall be introduced, which shall be used for communication and the transmission of protection in an emergency. The portable transceivers shall have duplex communication and simplex communication functions using the maintenance channel (CH2), monitoring function of CCP voice communication channel (CH1), and function to transmit protection and transmission power of 1 W is considered.

The 150 MHz VHF band (Very High Frequency-band) is considered as the frequency band used for train radio systems on the Line 5. Other principal features considered for the portable transceivers are TDM/TDMA as the access method, 4 MHz transmission/receiving frequency interval, channel spacing 25 kHz, modulation method π/4 shift QPSK, and transmission power of 5 W.

When the construction project of the Line 5 is materialized, Study Team will contact the Radio Frequency Directorate (RFD) of Hanoi for application of used frequency and adjust the plan to the frequency band assigned.



Source: JICA Study Team

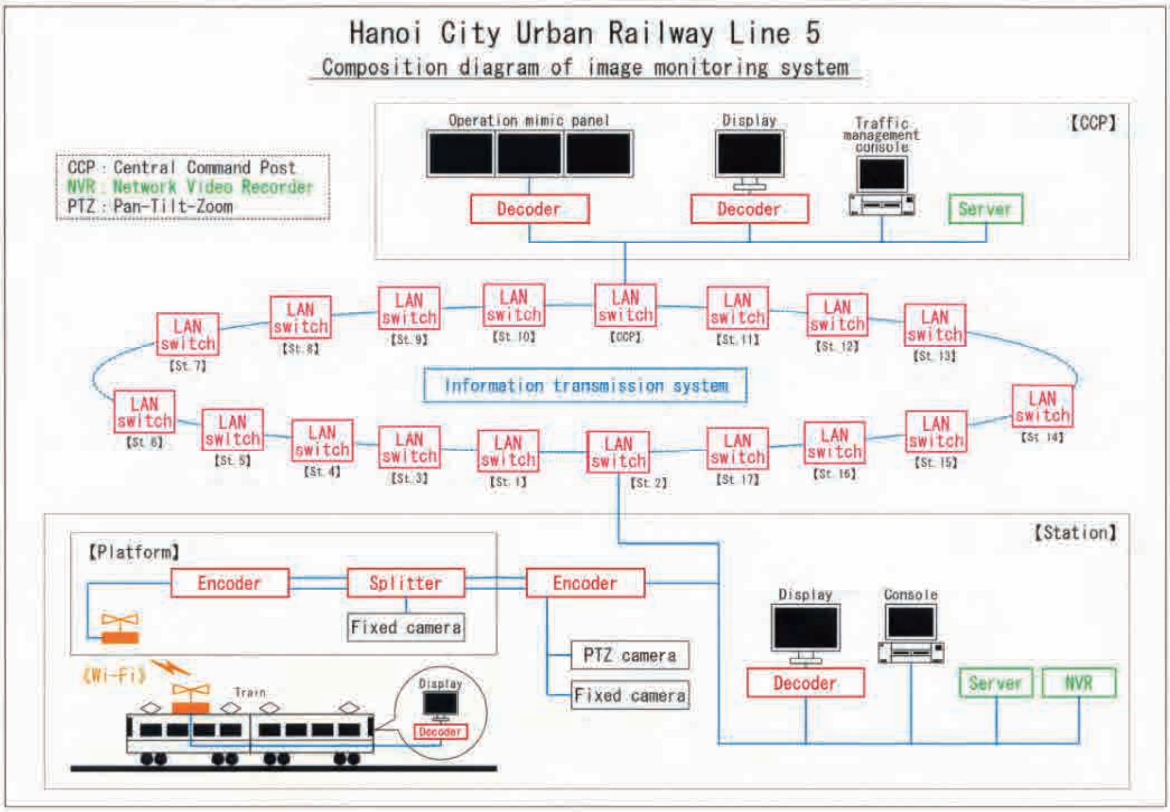
Figure 3.7.9 Composition diagram of train radio facilities

(4) Image monitoring system (see Figure 3.7.10)

The image monitoring system shall be introduced for remote monitoring of passenger status on the platforms, at concourses, gates, elevators, and escalators, and of trains at the platforms. The image monitoring system shall consist of cameras installed at various locations on the platforms; at the concourses, gates, elevators, escalators of the stations; monitoring displays and decoders installed in the station offices; and encoders, recorders, etc., installed in the communication equipment rooms.

Images taken at the stations are digitized by the encoder before transmission and displayed on the monitoring display after conversion to analogue signals by the decoder. The system shall allow monitoring of images on the operation mimic panel and the traffic management console in the CCP via information transmission system.

The fixed cameras and PTZ (pan-tilt-zoom) cameras shall be located as appropriate depending on the locations in the station. Direction and zoom control of the PTZ camera shall be made remotely by the station office and the CCP. Images from the monitoring camera on the platform shall be available on the monitoring display in the driver’s cab distributed using Wi-Fi technology when the train is in the station.



Source: JICA Study Team

Figure 3.7.10 Composition diagram of image monitoring system

(5) Passenger information system (see Figures 3.7.11 and 3.7.12)

The passenger information system (PIS) shall be installed to provide passengers on the platforms and concourses of the stations with information on the destination and the departure time of the trains operating. The PIS receives the train schedule from the ATS (automatic train supervision) system of the signaling system and automatically indicates destination, departure time, etc. of the trains on the train destination indicating panel on the platforms or in the concourses. It can also display a variety of information entered by the CCP or each station as free format messages, including the delay time and status when the train schedule is disrupted. In addition to the indication of the above, the automatic broadcasting system shall be installed to provide announcement for guidance and notice to passengers on the platform when the train is arriving and departing.

Source: Study Team

Figure 3.7.11 Destination indicating panel (platform)

Source: Study Team

Figure 3.7.12 Destination indicating panel (concourse)

(6) Other communication systems

1) Telephone system

In order to facilitate smooth operation, private telephone systems, such as the command telephone system connecting the CCP, depot, and stations, and electricity command telephone system, telephone system within premises, direct telephone system between Line 5 substations, etc., shall be installed in addition to the PBX (in-house) system.

2) Disaster preventive monitoring system

In order to prevent train accidents due to natural disasters and ensure the safety of train operation, a disaster preventive monitoring system shall be installed. Meteorological observation equipment (anemometers, thermometers, hygrometers, pluviometers, and barometers), seismic warning system, river water-level warning system, etc. shall be installed in appropriate locations along the wayside of Line 5 as the disaster preventive monitoring system.

3) Alert system

(i) Anti-theft alarm system

Anti-theft alarm systems shall be installed that detect unauthorized entry into the station offices during midnight hours and raise an alarm in the nap room.

(ii) Platform emergency alert system

The platform emergency alert system shall be installed that alerts the train drivers and station personnel of an emergency situation when it is detected by pressing the emergency button located on the platform.

(iii) Vehicle intrusion detection system

The vehicle intrusion detection system shall be installed to detect a motor vehicle that intrudes onto the track in the section where the Line 5 runs along Thang Long Road and to provide an alert to the CCP, neighboring stations, and trains.

3.8 Plan of Automatic Fare Collection (AFC) systems

3.8.1 Basic concept of AFC

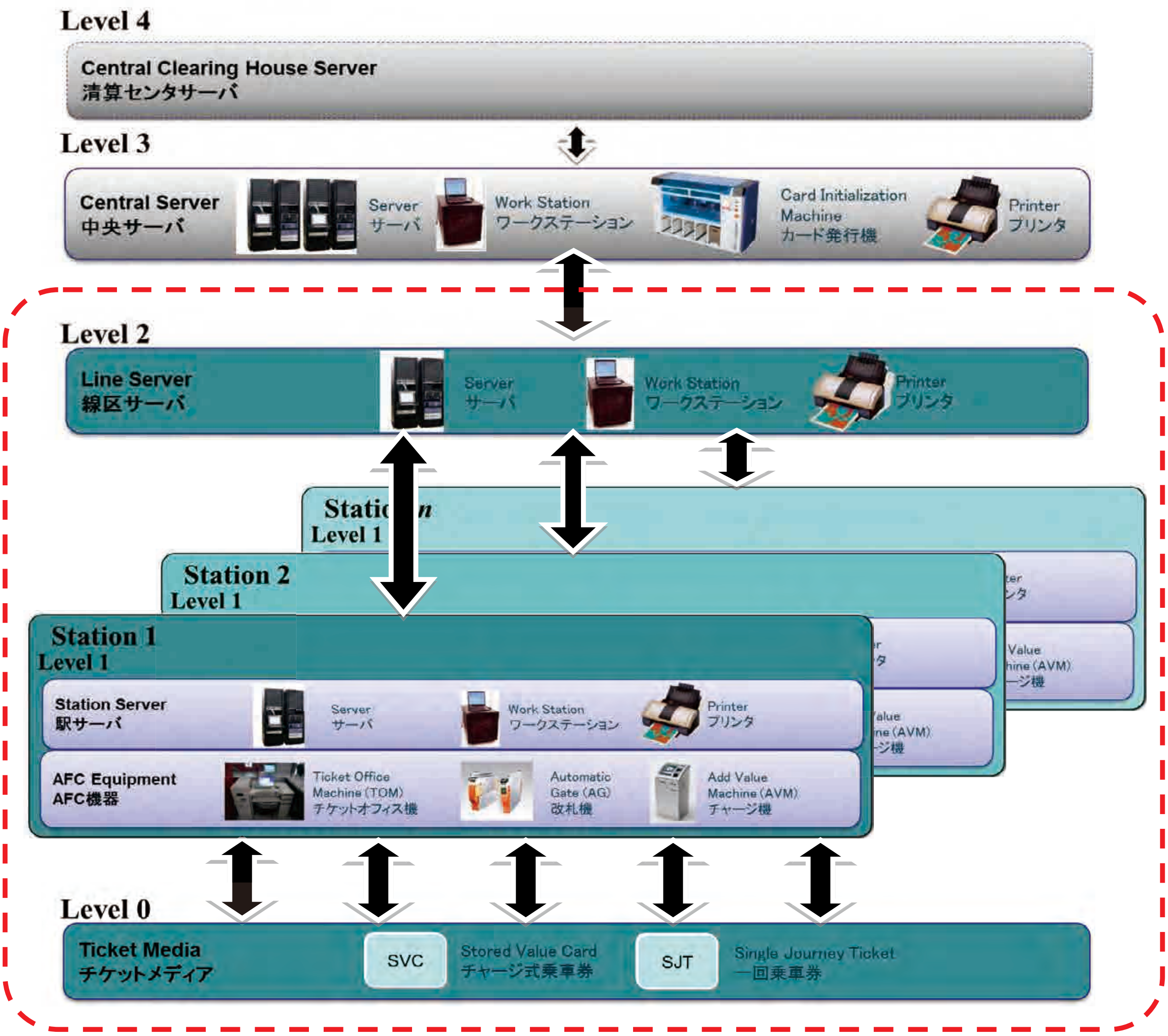
Important points in the basic concept of AFC are that they are capable of high-speed processing with few errors, highly confidential and safe, and flexible and compatible with expanding services in the future. Thus, contactless IC cards are adopted as passenger tickets.

There are many advantages of adopting AFC for both railway operators and passengers. As for merits of railway operators, for example, analyzing OD data allows us to identify passenger flow, and we can use the information to create proper operation plans. In addition, the use of highly confidential IC cards prevents forgery of cards and unauthorized use, enabling us to properly collect fares from passengers.

By recharging money to SVC (Stored-Value Card) after purchasing it, passengers can always take trains without purchasing tickets. In future, the uses of the card can be extended by giving the extensibility of the system can be used not only for using the railroad but for shopping at stores.

3.8.2 AFC device installation plan

The following procedures are expected for the AFC system configuration in the Line 5. The Line 5 will include up to the line server in Level 2 indicated in the red dashed box in Fig. 3.8.1. It is desirable for the upstream servers in Level 3 and Level 4 to be shared with other lines and managed together rather than being independently retained in Line 5.



Source: JICA Study Team

Figure 3.8.1 Composition diagram of AFC systems

(1) Level 0 Ticket media

Adopt SJT (Single-Journey Ticket) and SVC (Stored-Value Card) as ticket media used by passengers.

1) SJT (Single Journey Ticket)

SJT stands for “Single-Journey Ticket,” meaning it is effective for one trip. Station staff will issue SJTs using machines for issuance of IC card and sell them to passengers at teller windows in stations. No deposit is charged because SJTs are collected when passengers get off the train.

2) SVC (Stored-Value Card)

SVC stands for Stored-Value Card, and passengers can use the card many times by charging money to their IC cards.

As for the SJT, station staff will issue new SVCs using machines for issuance of IC card and sell them to passengers at teller windows in stations. Then, passengers charge money to their SVCs at Add Value Machines in stations. A deposit is collected for issuing a new SVC.

(2) Level 1: AFC device and station servers

1) AFC devices

i) Ticket office machine

Ticket office machine can issue SJTs and SVCs and rewrite information of the cards. They are installed in station operation rooms near automatic gates.

Station staff will issue new SJTs and SVCs using ticket office machines and sell them to passengers at teller windows in stations.

In case passengers who have SJTs do not store enough money in it, station staff will receive the balance, rewrite information of the cards, and return them to the passengers. The passengers can go out of automatic ticket gates by utilizing the rewritten cards.

Source: JICA Study Team

Figure 3.8.2 Ticket office machine

ii) Automatic ticket gates

The gates open and let passengers enter stations when passengers touch the readers on automatic ticket gates with their SJTs or SVCs.

Passengers with SJTs enter stations by touching the readers with their SJTs and leave stations by inserting their SJTs into automatic ticket gates. They are allowed to leave stations when enough money is stored on their SJTs. If the money stored on the SJT is insufficient, passengers pay the balance to station staff at station offices as they leave the stations after information of the SJT is rewritten.

Passengers with SVCs can pass through gates by touching readers with the SVC to both enter and leave stations. If the money stored on the SVC is insufficient when leaving stations, passengers charge money using Add Value Machines installed inside the gates to leave the stations.

Various types of doors for automatic gates are available. Examples are shown below. Study team will examine which type to adopt in the future.

Source: JICA Study Team

Figure 3.8.3 Automatic ticket gates

Source: JICA Study Team

Figure 3.8.4 Reader

iii) Add Value Machine for IC cards

Add Value Machines are used to charge money to SVCs. Add Value Machines for IC cards are placed both inside and outside ticket gates. If the balance on an IC card is insufficient when leaving the station, passengers charge money to their IC cards using the Add Value Machines placed inside ticket gates.

Source: JICA Study Team

Figure 3.8.5 Add value machine

2) Station server

This system manages information for individual stations by integrating information from AFC devices in each station.

(3) Level 2: Line server

This system integrates information gathered by station servers to manage information of the entire Line 5.

3.8.3 Examination of the number of AFC devices to be installed

The number of passengers entering/leaving a station per hour during peak hours based on demand forecast and minimum composition of a passage become the grounds for determining the number of AFC devices to be installed. The minimum composition of passage is a set of 4 gates: an entry-only gate, an exit-only gate, a gate for both entry and exit, and a wider gate which can be utilized by handicapped people, and at least one set need to be installed. As a result of demand forecast, it is figured out that installation of two sets of the minimum composition at every station shall be enough to handle entering and exiting of passengers. In addition, the space where additional AFC devices can be installed will be made secure from the beginning, considering the increase in demand in the future.

3.8.4 Transport calculation and management system

As shown in the diagram of the system configuration, this system sorts the information on passengers entering/leaving automatic ticket gates and sales at ticket office machines, as well as the amount of charges made at Add Value Machines in individual stations and manages the information of all stations on railroad section servers. The movement of the passengers can be grasped by creating of OD data based on the information. Moreover, monetary transactions can be monitored. Therefore, unauthorized use of IC cards and embezzlement by station staff can be monitored.

Moreover, a system which the operation of AFC devices can be monitored by is also adopted for upstream servers. Such a system allows quick responses in the case of malfunctions or accidents.

Such transport calculation and management system that allows integrated management of the entire system will be adopted.

3.8.5 Identification of problems

(1) Measures for promulgation

One of the measures to encourage passengers to continue using railroads is to promulgate the use of SVCs. Study team is worried that the local people’s means of transportation will not shift from automobiles and cars to trains simply by installing rail tracks and operating trains. Therefore, strategic efforts to promulgate trains should be employed. Some proposals to promulgate SVCs are described below.

1) Set No-motorbike Day

Set a No-motorbike Day on the opening day of Line 5 and sell one-day passes in order to decrease the traveling with motorbike. This campaign would publicize the convenience of trains to the local people and give them opportunities to use the trains. Also, passengers with the one-day pass will receive a discount for a deposit of a SVC.

2) Premium charging

The priority during the initial phase after the opening of Line 5 will be to encourage passengers to have SVCs. Set premier charging rates for passengers with SVCs to encourage them to continue using trains. It is expected that passengers will choose using trains by receiving profitable premium rates.

This campaign will also increase the number of SVCs issued by emphasizing that SVCs are more advantageous than SJTs.

(2) Bills to be accepted

Add Value Machines that passengers will use will only accept 10,000 VND and larger bills. Station staff will exchange bills smaller than 10,000 VND.

There are nine types of bills, and increasing the types of bills to be accepted requires the storage of many bills as change, which is not desirable in terms of efficient cash flow. Such a system is also disadvantageous because it increases the risk of theft. It is necessary to consider the types of bills to be accepted in Add Value Machines for IC cards.

3.9 Station square

3.9.1 Concept as a traffic junction

The means of passenger movement is a combination of various modes of transportation. They are selected to suit different purposes and the efficiency of passenger movement from individual transportation, such as motorcycles and bicycles, to mass transit such as trains. Traffic junctions are places where these modes of transportation are integrated, and passengers transit between modes of transportation.

Since congestion of road traffic has been a problem because of so many motorcycles, especially in the traffic conditions of Vietnam, it is expected that the utilization of motorcycles shall be shifted to railways, one of the public transportation modes, in the vicinity of the railway station. In order to construct parking lots for motorcycles and bicycles near the station, it is important to ensure that space. As mentioned below, if the construction structure at the city center is elevated, it is easy to secure a large space in close proximity to the train station and shall be possible to utilize the space with multiple purposes not only for the construction of parking lots but for commercial use and public facilities, etc.

Moreover, candidates for realizing the ideal structure as shown in Figure 3.9.1 are elevated stations in the urban area and those are St. 1 to St. 5. For stations in the suburban area, in addition, it is also possible to construct parking lots at all the stations, even though there would be some problems with land acquisition. Therefore, all stations are candidates, but if prioritization is required, it is effective to construct parking lots at the stations, excluding connecting stations with other lines, where there is no railway in the station sphere in the case of urban areas and at the stations in suburban areas in order to reduce the influx of motorcycles to the city center.

Traffic junctions are expected to process traffic in which passenger's transit to other modes of transportation and other lines in addition to services as an urban center, such as a station building and place to transmit information. The development of these features increases convenience. Therefore, the expected functions of stations are not limited to just being a transit point; rather, stations are expected to become places for people to gather for work and shopping and to become a source of information to create energetic cities.

3.9.2 Stations in urban areas

Stations in urban areas are planned to have entrances and exits to fit the current roads in both plans for elevated stations and underground stations in the railway plan for Line 5. Therefore, the construction of large station squares, such as those in suburbs, which will be described later, is impossible in terms of land uses. However, the areas surrounding urban stations will have functions as traffic junctions. For example, as shown in the Figure 3.9.1, the plan for elevated stations is based on providing convenient spaces by efficiently using spaces under overpasses to build motorcycle and bicycle parking. Urban stations will also have facilities, such as bus terminals and taxi stands, near the entrances and exits of pedestrian bridges or under overpasses to smoothly and efficiently process the transit between trains and buses or taxis for improved convenience. These facilities will further encourage uses of trains.

Re-development of areas in front of stations is possible in the future, and the plan for elevated stations makes it easy to make connections with commercial buildings near the stations.

Source: JICA Study Team

Figure 3.9.1 Image of utilizing the space under the elevated structure

3.9.3 Stations in suburbs

Convenient station squares and spaces for passengers are proposed for stations in suburbs so that facilities containing various living and cultural aspects, including commercial, cultural, and living functions, can be constructed in the spaces in front of stations.

As shown in Figure 3.9.2, one of the plans proposes an over-track station building on the median strip (the width is about 20 m) of Thang Long Road as a ground-level station in the suburbs, and a concourse is constructed on the second floor. The concourse is placed in the center of the station, and people will access the station square via the pedestrian bridge built across the highway, green belt, and sidewalks. Meanwhile, a traffic square is provided at the station square near the entrance/exit of the pedestrian bridge for smooth and efficient connections between trains and automobiles (buses, taxis, private cars) or motorcycles as a traffic junction between railway traffic to road traffic. This plan encourages the use of public transportations.

The proposal for station squares in suburbs in this plan is established while paying attention to the following points.

(1) Secure safe, comfortable pedestrian spaces (secure spaces where pleasant plants and arts can be arranged)
(2) Smooth accessibility to railroad stations
(3) Secure safe paths for automobiles and motorcycles
(4) Secure bus paths, bus terminals, taxi paths, and taxi stands in station squares.
(5) Place a motorcycle parking along automobile and motorcycle paths for the efficient layout of station squares.
(6) Secure spaces for people to take families to/from offices and schools by automobiles and motorcycles (Kiss & ride areas) in station squares
(7) Secure spaces to provide additional motorcycle parking to prevent motorcycles from overflowing into station squares when passenger demand is greater than expected in the station territory
(8) Secure areas where service facilities, such as commercial facilities and information areas can be installed when the population around stations increases and cities are built

In addition, safe pedestrian spaces should be secured in the actual development by installing steps and fences to prevent motorcycles from driving onto the sidewalks. This plan provided the basic concepts of development plans for station squares, but the administration is responsible for actual development, and they need to coordinate with railroad companies.

Figure 3.9.2 Image of a station located in suburbs

Source: JICA Study Team

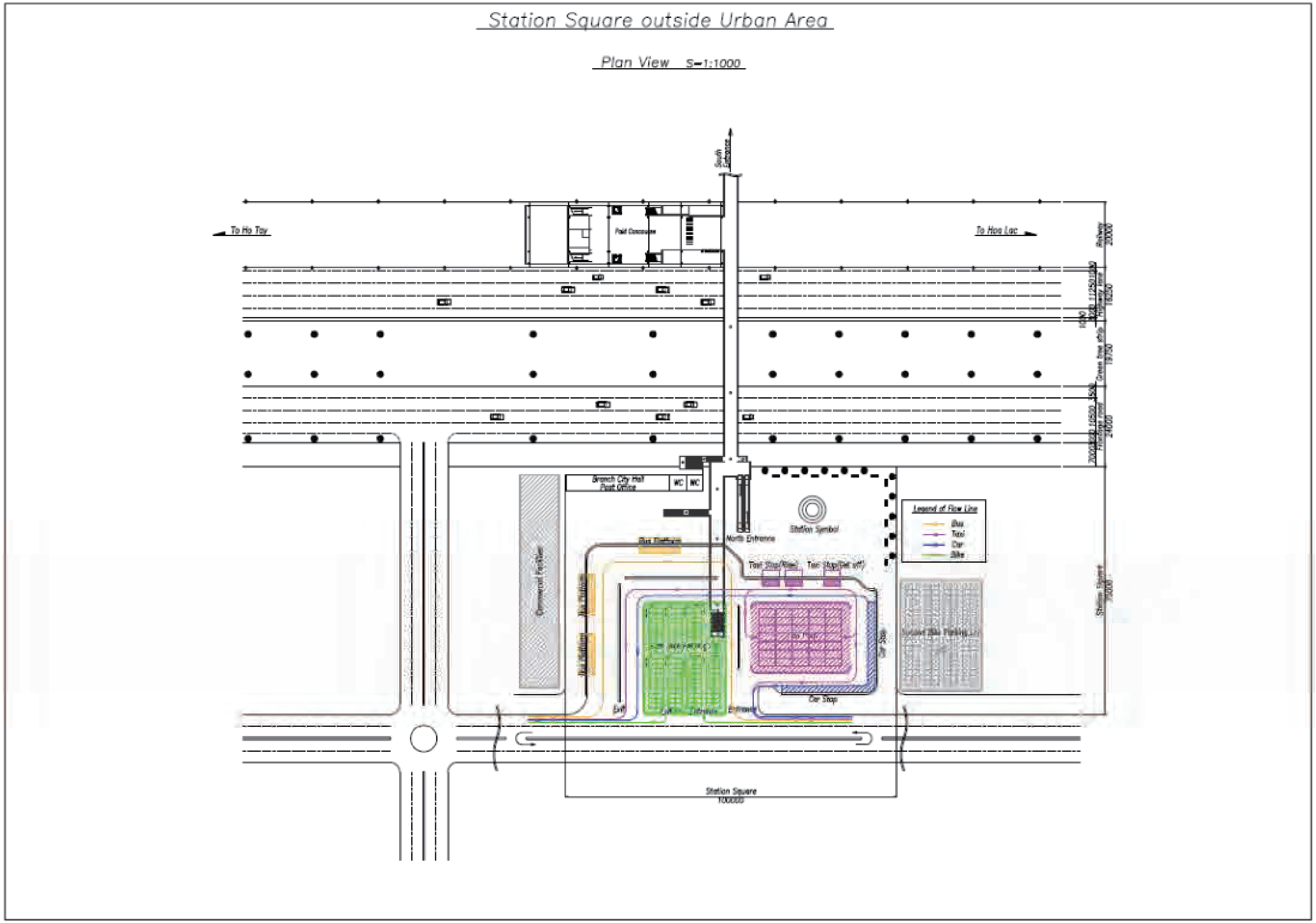


Figure 3.9.3 A station and station square in the suburbs Source: JICA Study Team

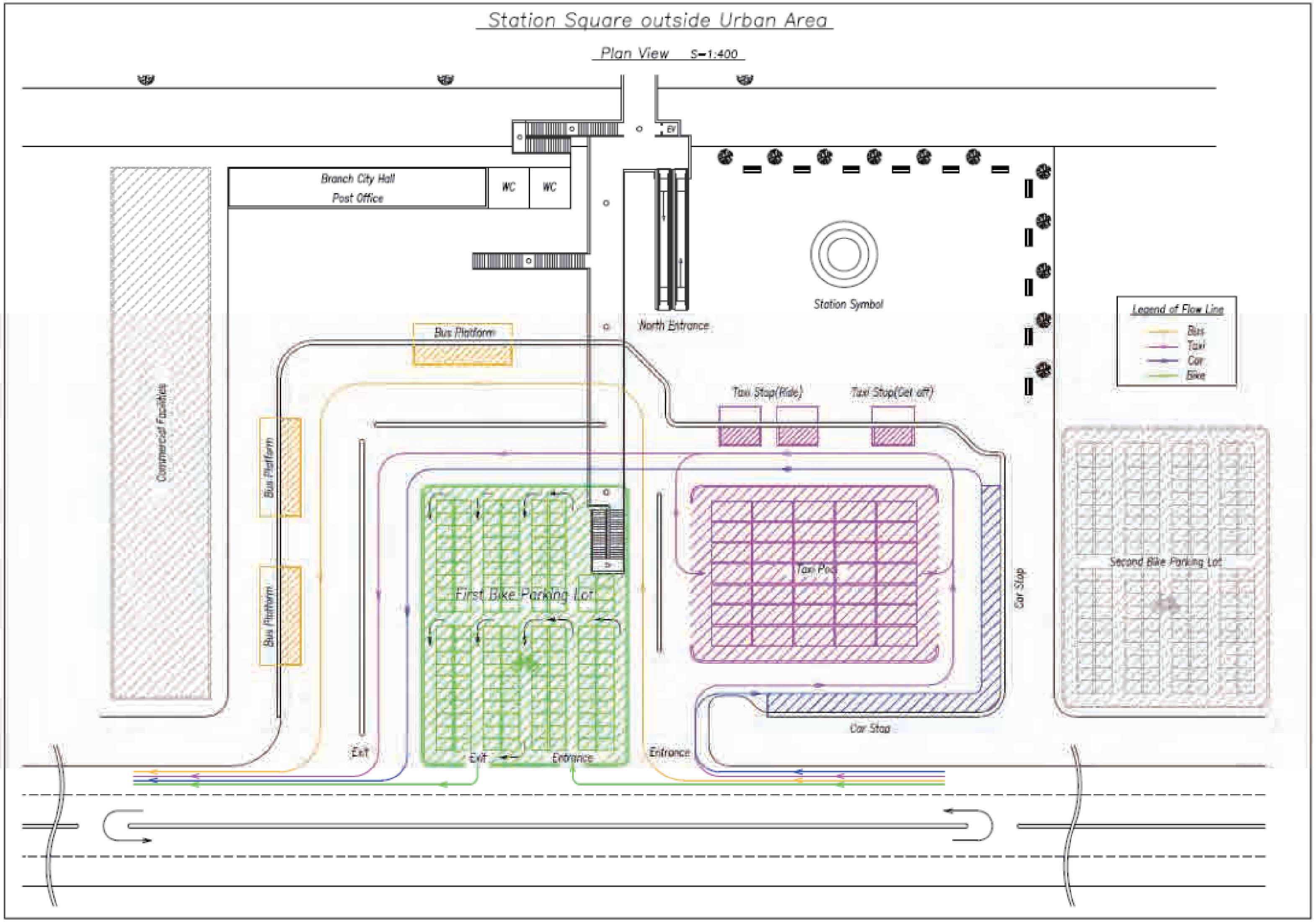


Figure 3.9.4 Layout of a station square in suburbs Source: JICA Study Team

3.10 Technical terms and other considered matters

3.10.1 Descriptions of technical standards and terms

(1) Railroad track and roadbed

1) Gauge

The gauge is 1,435 mm, which is widely used around the world and in other lines planned for construction in Hanoi.

2) Minimum curve radius

(i) The curve radius adopted in main tracks of urban railway (not including curves along platforms) shall allow trains to drive at a design speed in principle.

(ii) For the curve radius of main tracks, despite the stipulation in the last section, a curve radius suitable for the curving performance of applicable trains may be adopted by speed limit of the trains under special circumstances. Yet, the radius shall be 200 m or more in such cases.

(iii) The curve radiuses at curve incidental to turnout of the main tracks and stations shall be 100 m or larger.

(iv) The speed in curve shall be less than the value obtained by calculation of the equations below.

(a) The speed in curve in general:

$$V = \sqrt{127(C_o + C_d)R/G}$$

V: Train speed (km/h)
Co: Actual cant (mm)
Cd: Cant deficiency (mm)
R: Curve radius (m)

When the gauge (G) is 1,435 mm,

$$V \leqq 0.298\sqrt{(C_o + C_d)R}$$

(b) The speed in curve at the curve incidental to turnout

The speed in curve at the curve incidental to turnout shall be determined assuming a cant of 0 and adding a safety factor for overturning of the train on the outside of a curve (not including a turnout with cant).

$$V = \sqrt{127GR/(2aH)}$$

V: Train speed (km/h)
H: Height of the train’s center of gravity (mm) [1,650 mm]
G: Gauge 1,435 (mm)
R: Curve radius (m)
a: Safety factor [high-performance train: 3, ordinary train: 3.5, diverging curve: 5.5]

$$V \leqq \sqrt{3.2R}$$

3) Minimum curve length/minimum straight length

(i) The length of the curves on the same radius along a main track shall be longer than the length of the train except for the curve incidental to turnout. Transition curves may be used on all curves, however, when it is the only option due to geographical limitations or other restrictions.

(ii) A straight line longer than the length of the train shall be provided between two transition curves when two curves are located in close proximity to the main track. Two transition curves may be connected directly, however, when there are geographical or other limitations.

(iii) A five-meter or longer straight line without cant shall be provided between two curves on a side track in principle.

(iv) A straight line longer than the length of the train must be provided between a turnout and a nearby curve from the beginning or the end of a turnout to the start of a curve. However, the following line shapes may be used when necessary.

(a) Provide a five-meter or longer straight line from the beginning or the end of a turnout to the start of a curve.

(b) Provide a five-meter or longer straight line from the toe of a crossing to the start of a transition curve located behind.

(c) Locate the start of a transition line at the end of a turnout when a nearby curve includes a transition curve.

(v) The distance between the end of a turnout and the start of a curve must be five meters or longer when a nearby curve does not include a transition curve.

(vi) If all of the above cannot be adopted, examine the safety of the conditions of special alignment.

4) Cant

(i) An outward centrifugal force is applied to the train when it passes through a curve at a certain speed. The outer rail is placed higher than the inner rail depending on the train speed and a curve radius (this means cant). Cant is set to prevent overturn of the train due to centrifugal force, discomfort to passengers, and damage to tracks (this means cant.).

(ii) All curves on main tracks shall have cant except for curve incidental to turnout. Curves on side tracks shall have cant when necessary.

(iii) Maximum cant and permissive cant deficiency shall be less than the values in the table below.

Table.3.10.1 Maximum cant and allowable cant deficiency

	Gauge: 1,435 mm
Maximum cant	180 mm
Permissive cant deficiency	90 mm

Source: The Study on Building the National Technical Regulation and Standard Set for Railway, Final Report

(iv) The cant on a circular curve of a railroad shall be appropriate for the centrifugal force applied on a driving train.

(v) The cant of ordinary railroads shall be gradually decreased in accordance with the following:

(a) The cant shall be gradually decreased throughout the length of a transition curve.

(b) Use the following conditions when there is no transition curve (except when two curves in the same direction are connected).

・Distance of diminishing of the cant in case of linear diminishing shall be as follows:

The distance shall be at least 300 times greater than the cant when the maximum wheelbase of the train is 2.5 m or less.

The distance shall be at least 400 times larger than the cant when the maximum wheelbase of the train is larger than 2.5 m.

・Maximum grade of the cant in case of non-linear diminishing shall be as follows:

The grade shall be 1/300 when the maximum wheelbase of the train is 2.5 m or less.

The grade shall be 1/400 when the maximum wheelbase of the train is larger than 2.5 m.

5) Gauge widening

(i) The maximum value of the slack of an ordinary railroad shall be the value specified in the table below.

(ii) Gauge widening shall be gradually decreased based on the following standards.

(iii) Gauge widening shall be set through the entire length of a transition curve.

Table.3.10.2 Maximum values of gauge widening

Gauge widening (mm)	Gauge: 1,435 mm
Maximum value (main track, side track)	15 mm
When the above value cannot be used	25 mm

Source: The Study on Building the National Technical Regulation and Standard Set for Railway, Final Report

(iv) Gradually gauge widening shall be diminished in the section which is more than the length of the wheelbase of rolling stock running on the circular curve. This rule does not apply in case of curve incidental to turnout.

6) Transition curve

(i) The length of a transition curve on an ordinary railroad shall be greater than the maximum values calculated based on the table below depending on categories of the design speed. The values in parentheses may be adopted for L_2 and L_3 in sections where the maximum speed is 70 km/h or less.

Table.3.10.3 Length of transition curve

Length of a transition curve \ Maximum speed		More than 110 km/h to 150 km/h or less	More than 90 km/h to 110 km/h or less	More than 70 km/h to 90 km/h or less	70 km/h or less
L_1	When the wheelbase is 2.5 m or less	300 C			
	When the wheelbase is more than 2.5 m	400 C			
L_2		10 CKV	10 CKV	8 CKV	8 CKV (7 CKV)
L_3		9 CdKV	9 CdKV	9 CdKV	9 CdKV (7 CdKV)

Source: The Study on Building the National Technical Regulation and Standard Set for Railway, Final Report

(1) L_1, L_2, and L_3 indicate transition curves (mm), C the actual cant (mm), Cd the cant deficiency (mm), and V the maximum speed on a curve (km/h).
(2) K shall be 0.75 when the gauge is 1,435 mm.
(3) Values in parentheses shall be used when other values cannot be used due to geographical limitations or other restrictions.

(ii) The length in L_1 in the table above shall be secured even when there are geographical limitations or other restrictions. Yet, this rule does not apply when running safety is verified by limiting train speed on curves if curve is curve incidental to turnout or circular curve with small cant.

7) Gradient

(i) The gradient of the main track shall be 35/1000 or less.
Yet, the gradient shall be 45/1000 or less when there are geographical limitations or other restrictions if the track is deadhead line (sections where trains carry no passenger), and the difference in elevation is 20 m or less.

(ii) The maximum gradient within a section where trains stop shall be 5/1000 or less. Yet, the maximum gradient shall be 10/1000 or less in sections where trains are not kept or disconnected as long as the gradient does not impede the arrivals and departures of trains.

(iii) When a plane curve has a gradient, correct the gradient while taking into account the resistance (curve resistance) associated with the curve and make it smaller than the maximum gradient of the applicable section.
Use the following equation to obtain curve resistance.
Curve resistance: r_c (kN/t)
$r_c = \frac{1000f(G+L)}{2R}$ (kN/t)
r_c: Curve resistance (kN/t) per ton of train weight
G: Gauge (m)
L: Wheelbase (m)

f: Friction coefficient between a rail and a wheel

R: Curve radius (m)

When substituting the following values into the above equation: G = 1.430, L = 2.100, and f = 0.2 (usually 0.1 – 0.27),

$r_c = \frac{353}{R} \fallingdotseq \frac{350}{R}$ (kN/t)

Curve resistance (corrected gradient) $= \frac{350}{R}$ (‰)

(iv) Tunnel resistance is a resistance caused by wind pressure fluctuation when the train passes through a tunnel. Correct gradient while taking account of a tunnel resistance when applicable section inside a tunnel is 500 m or longer to make the gradient smaller than the maximum gradient of the section. Tunnel resistance shall be as follows.

(a) Single line tunnel: rt = 2kN/t i = 2‰

(b) Double track tunnel: rt = 1kN/t i = 1‰

8) Vertical curve

(i) Provide a vertical curve in sections with variable gradients while taking into account train speed and train structures to secure the safety of train operations and the riding comfort of passengers. Yet, this rule does not apply when variations in gradients are small, train speed is low, or there is no risk of impeding the safe operation of trains.

(ii) Vertical curves of urban railways shall be greater than the following radiuses. Yet, these conditions do not apply when the running safety of train is secured depending on the conditions of design speed and train length.

Table.3.10.4 Radius of vertical curve

Radius of plane curve (m)	Radius of a vertical curve (m) Gauge: 1,435 mm
Including a straight line R ＞ 800 m	3,000 m (2,000 m)
R ≦ 600 m	4,000 m (3,000 m)
Gradient variation to which vertical curve may not be inserted (‰)	Less than 10‰

Values in parentheses shall be used when other values cannot be used due to geographical limitations or other restrictions.

Source: The Study on Building the National Technical Regulation and Standard Set for Railway, Final Report

(iii) Avoid existence of a vertical curve with a transition curve as much as possible.

9) Clearance gauge

(i) The standard clearance gauge is the sum of the width of the rolling stock gauge and 800 mm.

(ii) The standard clearance gauge may be greater than the sum of the width of the rolling stock gauge and 400 mm when trains with structures that do not allow passengers to stick their bodies out the window are the only trains that run on the line.

(iii) For sections that are not fenced to prevent trespassing on the premises of the railways, the standard top limit is 5.70 m in height, which is the sum of the standard height of 5.00 m, the height of a suspension system 500 mm, and an extra 200 mm in sections with no restrictions on the top of the rail tracks where trains operate via DC power. Yet, the top limit may be lowered when a safe distance is secured between the contact wire and the height of a folded pantograph in sections where people cannot easily enter, such as underground structures, elevated railway structures, tunnels, bridges, or fenced areas, or when a safe support system for the contact wire is adopted.

(iv) The standard clearance gauge on platforms shall be 1,110 mm from the rail level in the vertical direction and up to +50 mm from the rolling stock gauge in the lateral direction.

(v) Facilities which must be installed within the base limit of clearance gauge to inspect and clean a roof-top inspection stand and a washing station shall be clearly installed, after determining the design speed and place for installation and verifying safety. The rolling stock gauge may be set at +50 mm in such cases.

10) Width of formation level

(i) The width of the formation level of the main track shall be 3.00 m in sections with an embankment or excavation. The formation width shall be properly increased and decreased when there is cant. Yet, the formation width may be decreased when it is verified not to impede the functions of track structures and evacuation routes.

(ii) The width of the formation level in sections with elevated bridges or other structures shall be 3.00 m, which shall be properly increased and decreased when there is cant. The formation width may be decreased when it is verified not to impede the functions of track structures and evacuation routes.

11) Distance between centers of tracks

(i) The distance between the centers of the tracks of the main tracks shall be greater than the sum of the width of the rolling stock gauge and 600 mm.

(ii) The distance between the centers of the tracks shall be greater than the sum of the width of rolling stock gauge and 400 mm when trains with structures that do not allow passengers to stick their bodies out the window are the only trains that run in a section.

(iii) The distance between the centers of the tracks shall be greater than the sum of the width of rolling stock gauge and 400 mm in sections other than the main tracks.

(iv) The distance between the centers of the tracks shall be widened in curves depending on the car body displacement at curve.

(2) Structures and facilities

1) Elevated bridges

(i) The structures of elevated bridges shall include the earth structure, rigid-frame structure, and a bridge (concrete beam, PC concrete beam, compound beam, and steel girder), which are selected based on the conditions of the surrounding areas, landscape, environment of installation, and economic efficiency.

(ii) The head room of elevated bridges shall be provided based on road design standards at intersections or crossings with roads.

2) Underground structures

The types of underground structures include cut-and-cover tunnels (reinforced concrete, box-type rigid frame structure), shielded tunnels, and NATM tunnels, which are selected based on conditions, such as terrain shapes, geological conditions, number of rail tracks, environment of installation, and economic efficiency.

3) Depot and other facilities

Depot, train inspection facilities, and repair facilities shall have sufficient storage capacities and inspection and repair capabilities for trains to be stored there.

4) Track structures of urban railways

(i) Types of track structures include tracks with crushed stone ballast, tracks where PC sleepers are fixed onto concrete track beds, slab tracks, tracks where tie plates are fixed on concrete track beds, and other structures.

(ii) Track structures shall be adopted only when the safety for train operations is verified.

5) Facilities to prevent disasters

(i) Procedures for protecting facilities from disasters such as rain, river flooding, strong winds, and earthquakes shall be specified in advance. Specific measures for flooding shall be implemented for facilities in underground stations and sections.

(ii) Gauges and meters such as rain gauges, water level gauges, wind gauges, and seismographs shall be properly installed to prevent disasters caused by rain, river flooding, strong winds, and earthquakes, and the safety of trains and rail tracks shall be secured based on information obtained from them.

6) Evacuation facilities

(i) The following facilities that allow people to walk to escape in an emergency, such as trains stopping due to vehicle breakdown, shall be installed on the rail tracks including tunnels, bridges, and elevated bridges.

Table.3.10.5 List of evacuation facilities

Place to be installed	List of evacuation facilities
Evacuation routes	Walking routes -Indication of areas which block walking (side ditches, protrusions) -Facilities to prevent people from entering hazardous areas and indication of hazardous areas (electric facilities, machineries)
Tracks with bridge sleepers	walk boards and sidewalks on bridges
Tunnels	Lights, guide lamps, and indication of distance to nearby stations

Source: The Study on Building the National Technical Regulation and Standard Set for Railway, Final Report

7) Measures to be implemented in sections with an over bridge or trenches

(i) Install facilities to prevent objects from falling onto the rail tracks in areas where automobiles or objects may fall onto the rail tracks, such as sections where a road over bridge crosses a rail track or a rail track is installed in a trench.

(ii) Install guardrails or concrete walls in sections where automobiles may fall onto the rail tracks, such as sections where rail tracks are installed in trenches.

(iii) Install guardrails or fences to prevent objects from falling in sections with over bridges or bridges where objects may fall onto the rail tracks.

(iv) In addition to the facilities above, install facilities to detect falling objects in sections where increased safety is required.

(3) Station

1) Facilities in stations

(i) Passenger facilities shall be installed in stations for the number of passengers expected in the stations.
Passenger facilities in stations include platforms, traffic facilities (passages, concourses, stairs, over bridges, elevators, escalators, etc.), service facilities (ticketing booths), passenger spaces (waiting rooms), facilities for operation of stations, restrooms, lights, and water supply/wastewater facilities.

(ii) Stations shall have signs, such as guide signs, location signs, information signs, and signs of restrictions to properly guide passengers to ticketing booths, concourses, platforms, and restrooms.

2) Platforms

(i) Width and length of platforms

(a) The width of opposite platforms shall be 1.5 m or more at the ends of platforms and 2 m or more in the centers. The width shall be 5 m or more when stairs and other facilities are installed on the platforms.

(b) Widths of island platforms shall be 2 m or more at the ends of the platforms and 3 m or more in the centers. The width shall be 7 m or more when stairs and other facilities are installed on the platforms.

(c) The length of the platform shall be longer than the maximum overall length of car body, while the standard length shall be the sum of the maximum overall length of car body and 10 m. The length may be shortened by 10 m when platform doors or gates are installed.

(d) When installing stairs on the platform, the distance between the side of the stairs and the edge of the platform shall be 1.5 m or more, and the distance between a pillar and the edge of the platform shall be 1 m or more.

The distance between the side of stairs and the edge of the platform may be 1.2 m or more when platform doors are installed.

(ii) Height of platforms

(a) The standard height of the platform shall be 1,100 mm from the tread surface of a rail.

(b) Floor surfaces of trains and surfaces of platforms shall be as flat as possible. Floor surfaces of trains may be up to 50 mm higher than the tread surface of platforms. When floor surfaces of trains are lower than surface of platforms, the difference in height shall be up to 20 mm.

(iii) Distance between the train and the platform

(a) The standard smallest distance between the train and the platform shall be 70 mm in straight sections, and at least 50 mm shall be secured between the train and the platform.

(b) Widening of clearance gauge and inclination caused by cant shall be considered when platforms are in curved section.

(c) The distance between the train and the platform shall be up to 200 mm in sections where passenger doors are located. This rule does not apply, however, when a movable device to fill the gap is installed for passengers to get on and off the train. Passengers shall be notified of large gaps between trains and platforms through cautionary signs or announcements.

(iv) Equipment for the physically handicapped

(a) A slope, escalator, or elevator shall be provided at least one route between the platform of a station and a road so that people in wheelchairs can move between these facilities.

(b) Tactile ground surface indicator shall be installed on at least one route between the platform of a station and a road.

(v) Installation of platform doors and gates

(a) Platform doors (including movable gates (half-size platform doors)) or platform gates (fixed gates with openings at train doors) must be installed on platforms to prevent passengers from falling onto the rail tracks or collision between passengers and driving trains on platforms.

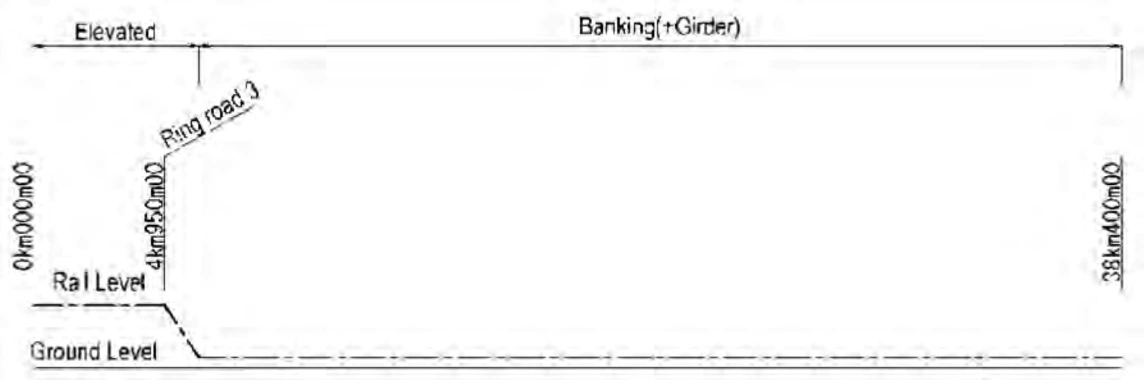
(b) This rule may not be applicable, however, the platform is wide and the number of passengers is small.

3.10.2 Discussions on the structure

As for the structure of railway line, plural combination about downtown and suburb was studied. As a result, in Chapter 3.4, the elevated or the underground type in downtown area is described. Here, the other alternatives are shown. Moreover the feature of each draft and comparison are summarized.

1) Idea of the elevated- ground level type

It was mentioned in 3.4.3.

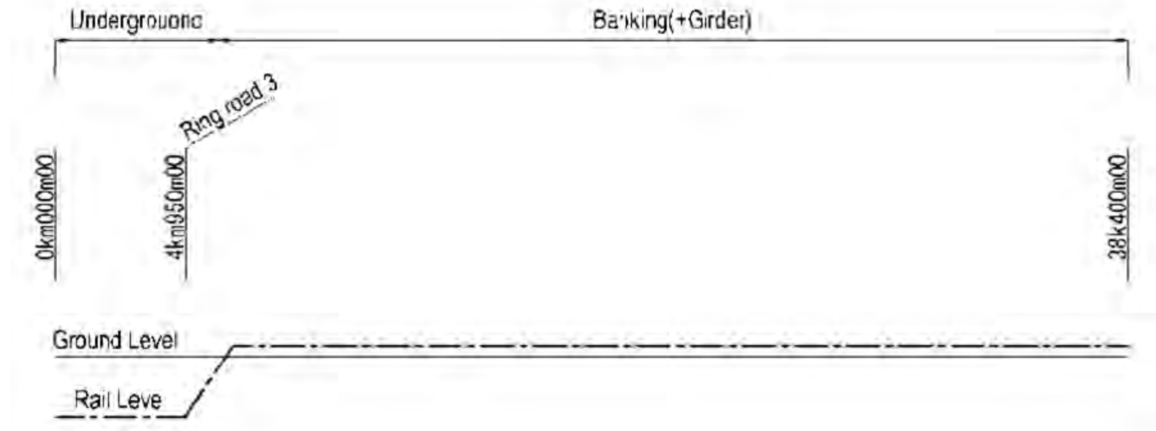


Source: JICA Study Team

Figure 3.10.1 Idea of the elevated-ground level type

2) Idea of underground-ground level type

It was mentioned in 3.4.4.

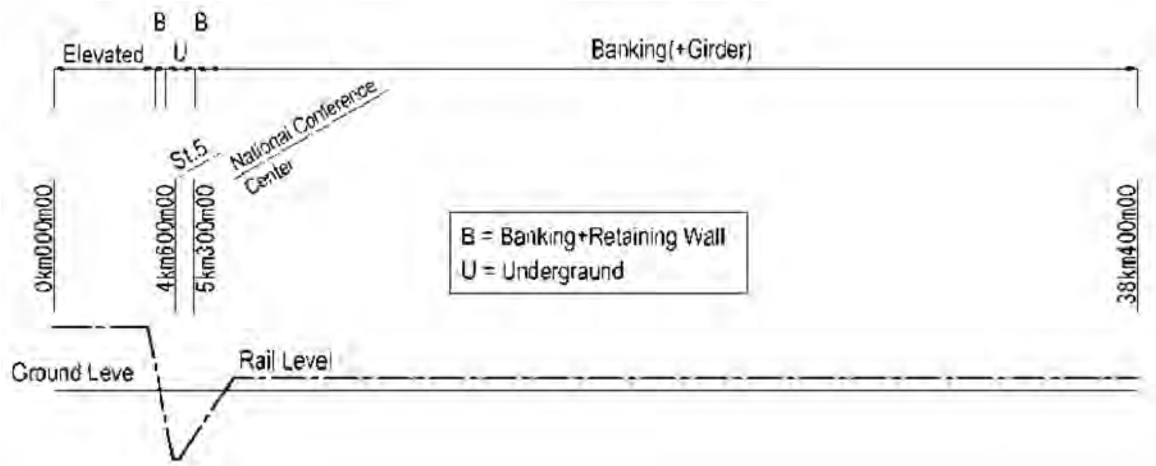


Source: JICA Study Team

Figure 3.10.2 Idea of the underground-ground level type

3) Idea of the elevated-underground-ground level type

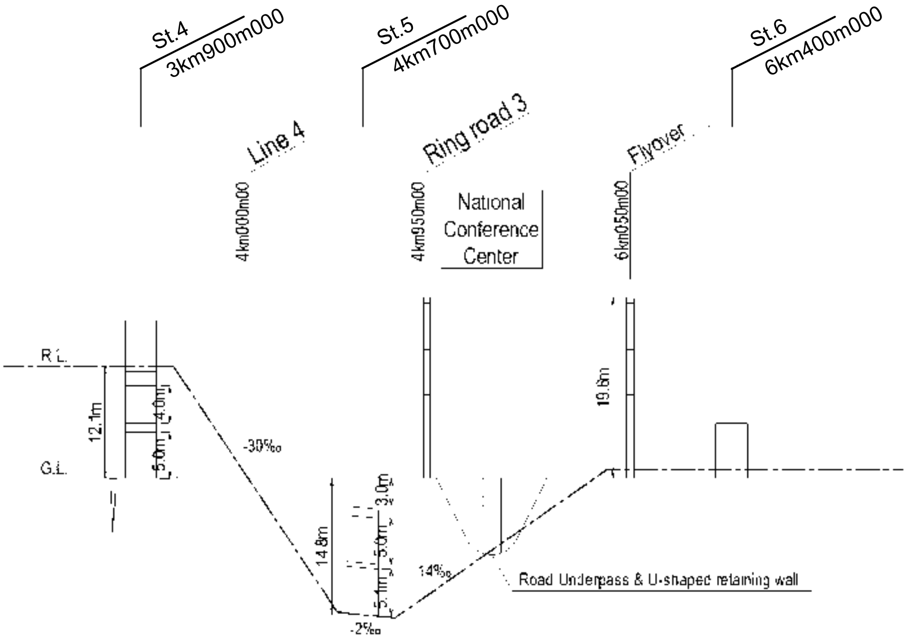
This is an idea to adopt the underground type at St. 5 and the national conference hall, the elevated type on the original point side and the ground level type on the terminal side. The elevated section and the ground level section will sandwich the underground section in the same way as referred to in the idea 1).



Source: JICA Study Team

Figure 3.10.3 Idea of the elevated-underground-ground level type

The difference between the elevated and the underground sections is about 27 m. In case these two sections are connected at a gradient of 30‰, the distance between St.4 and St.5 will be about 1.2 km (Fig 3.10.5) to make the Line 4 and the station on the Line 5 about 500 m apart. This cannot guarantee smooth interchanges in between.



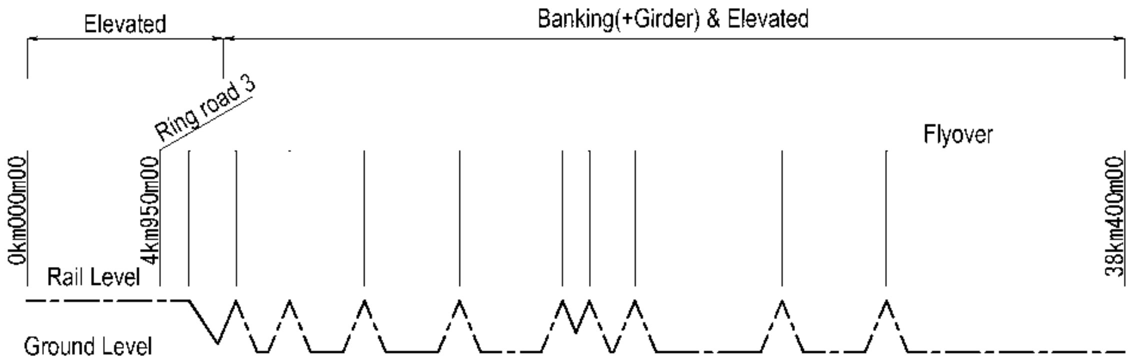
Source: JICA Study Team

Figure 3.10.4 Details of the station 5 and its vicinity in the idea 4).

4) Idea of the elevated- (ground level and elevated) type

This is an idea to adopt a structure of the elevated type from the starting point to the ring road 3 (4K950M point) in the same way as stated in the foregoing paragraph 1). Beyond the ring road 3, the railway will be constructed basically to have a structure of the ground level type and a structure of the elevated type on the viaduct to cross the Thang Long road.

Study team has a plan to lay tracks under the girders of the Thang Long road flyover viaduct. However, since agreement cannot be obtained after discussion with administration after discussion with administrator of the flyover viaduct, in case that the tracks cannot pass under the girders, they need be placed on the viaduct girders as stated above.



Source: JICA Study Team

Figure 3.10.5 Idea of the elevated- (ground level and elevated) type

Table 3.10.6 Comparison between different ideas

Item of comparison	Idea 1	Idea 2	Idea 3	Idea 4
from Starting point to ring road 3	Elevated	Underground	Partly underground	Elevated
from ring road 3 to Terminal point	Ground level	Ground level	Ground level	Ground & elevated
1. Alignment				
Horizontal alignment	◎	◎	◎	◎
Vertical alignment	◎	◎	○	×
2. Station distribution plan (Network)	◎	◎	△	△
3. Linkage with surrounding areas				
Communication with surrounding facilities	◎	△	△	○
Interchange with other railway lines	○	◎	○	○
Connection with motorbikes and buses	○	△	△	○
4. Landscape	△	◎	○	△
5. Construction work				
Road occupancy and lands for work	○	○	○	△
Construction cost	◎	△	△	×
Geological features	△	△	△	△
Construction period	○	△	△	○
6. Maintenance				
Inundation	◎	△	△	◎
Environment (Noises)	○	◎	○	○
(Vibration)	○	○	○	○
(Sunshine)	○	◎	○	○
Maintenance cost	○	△	△	△
Overall evaluation	◎	○	×	×

<Legend> ◎ : Best ○ : Good △ : Relatively difficult × : Difficult

Source: JICA Study Team

As shown in Chapter 3.4, the idea 1 as elevating of railway in downtown and the idea 2 as underground in suburb are indicated. Since construction cost is cheaper and worries about flood are necessary, the idea 1 has been proposed preferentially. As for the idea 3, formation of the railroad network in downtown area is a little difficult. Therefore, overall evaluation is estimated as ‘Relatively difficult’ from a viewpoint of promotion of utilization of railroad and the improvement of convenience of it. As for the idea 4, since the vertical alignment of the suburban area is difficult to construct and the extension of elevated construction becomes long further in order to solve this problem, it is estimated as ‘Difficult’.

3.10.3 Study on passing track

Now, according to the number and the arrangement of stations about Line 5, it is unnecessary to install a high-class train is not needed. In the future, however, when the number of stations is increased, it is necessary to install a high-class train in order to drive the railway trains from the center of downtown trains to the suburb in around 30 minutes. Moreover, it is necessary to install the passing track so that high-class train can pass the local train. Although the above is indicated in 3.4.8 (1), the detail drawings of each idea are shown as follows.

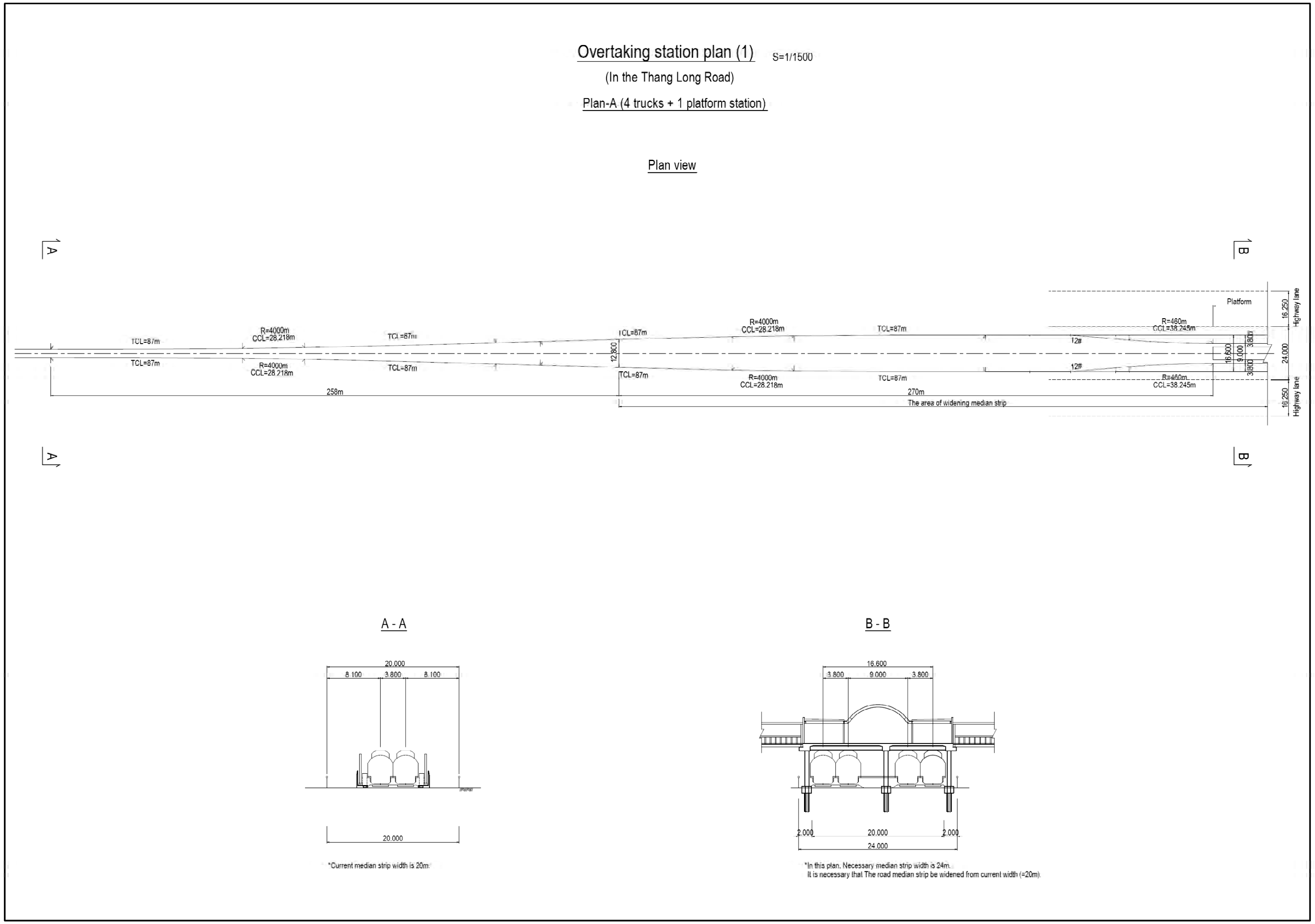


Figure 3.10.6 Study on passing track (1)

Source: JICA Study Team

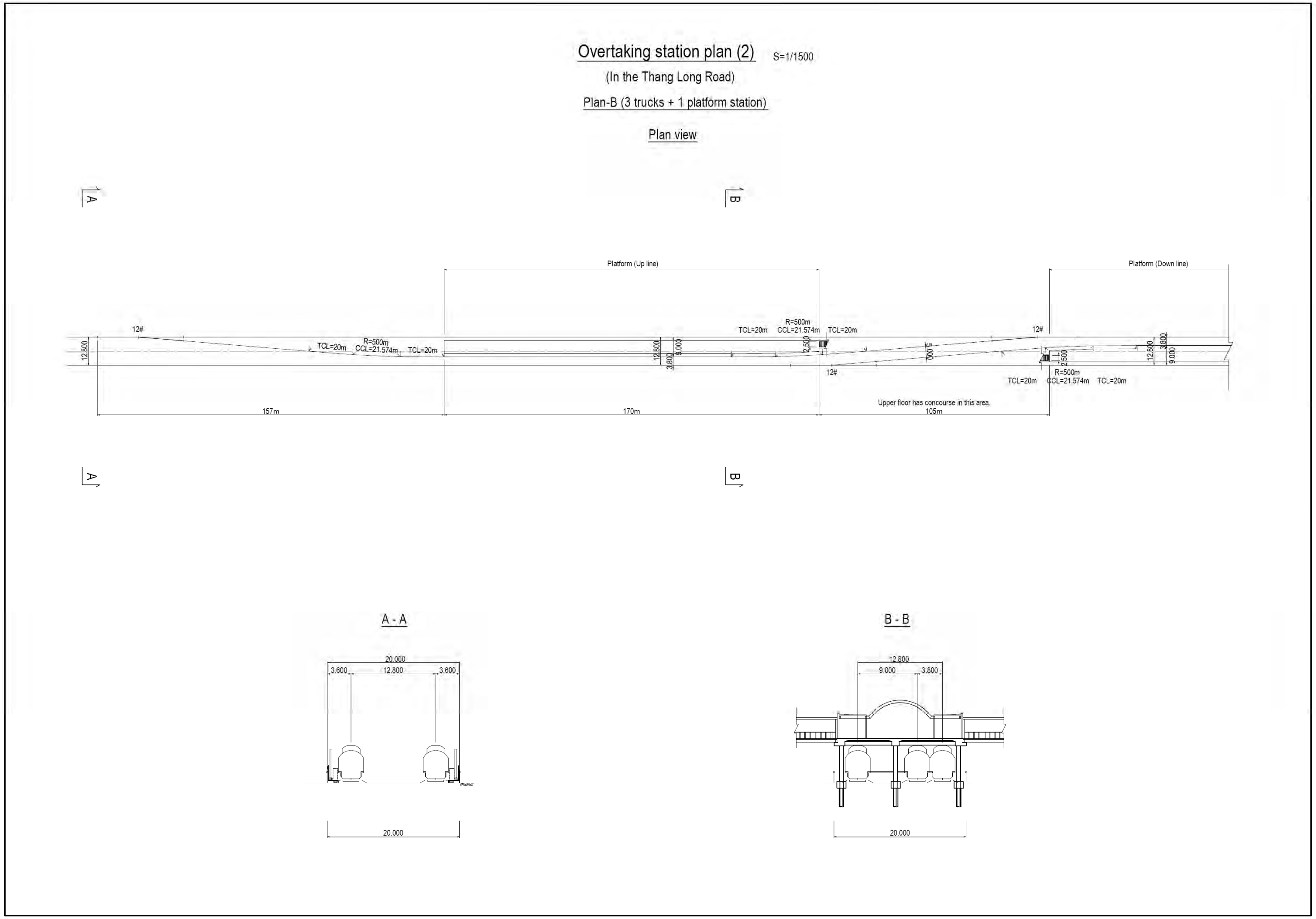


Figure 3.10.7Study on passing track (2) Source: JICA Study Team

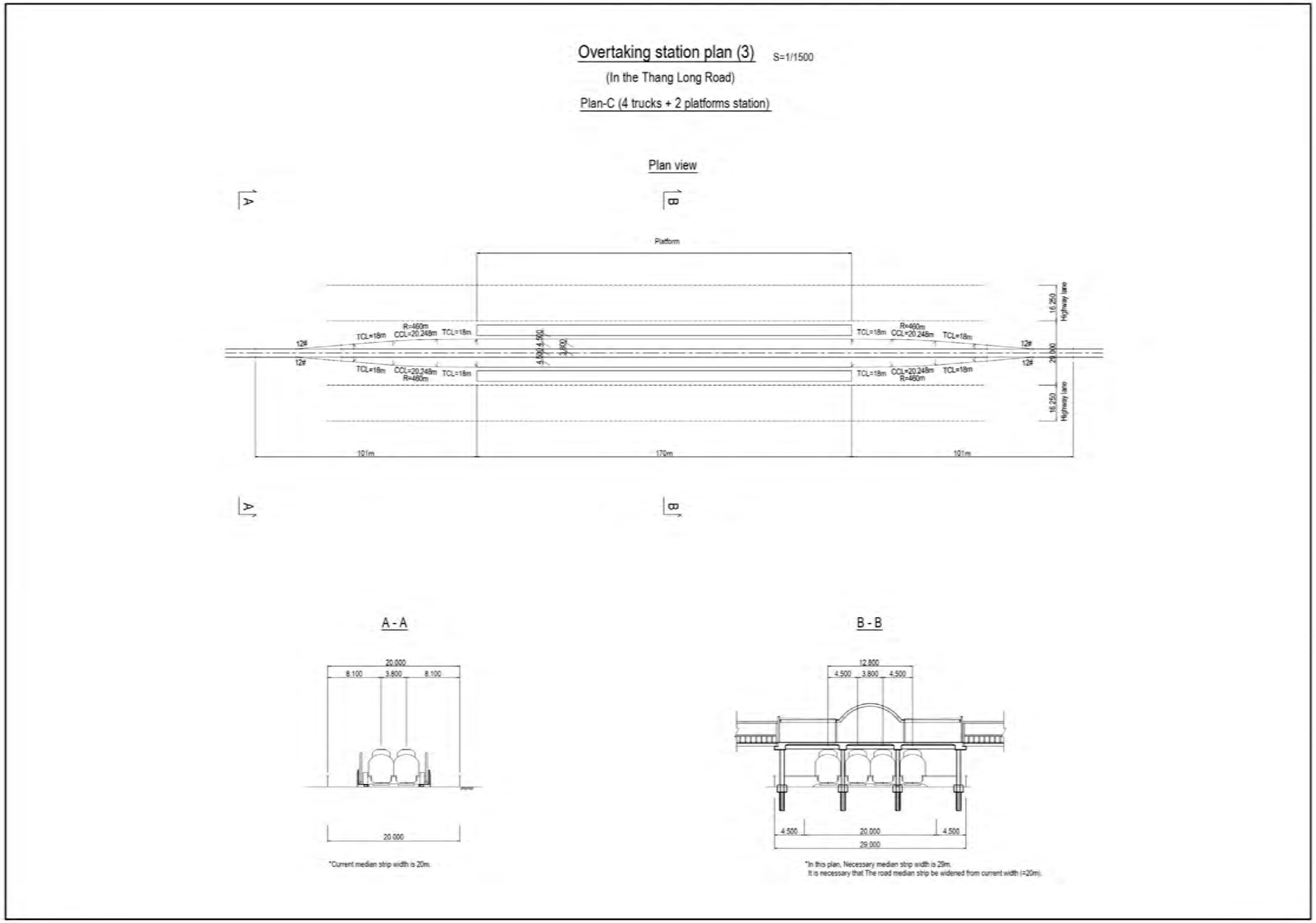


Figure 3.10.8 Study on passing track (3) Source: JICA Study Team

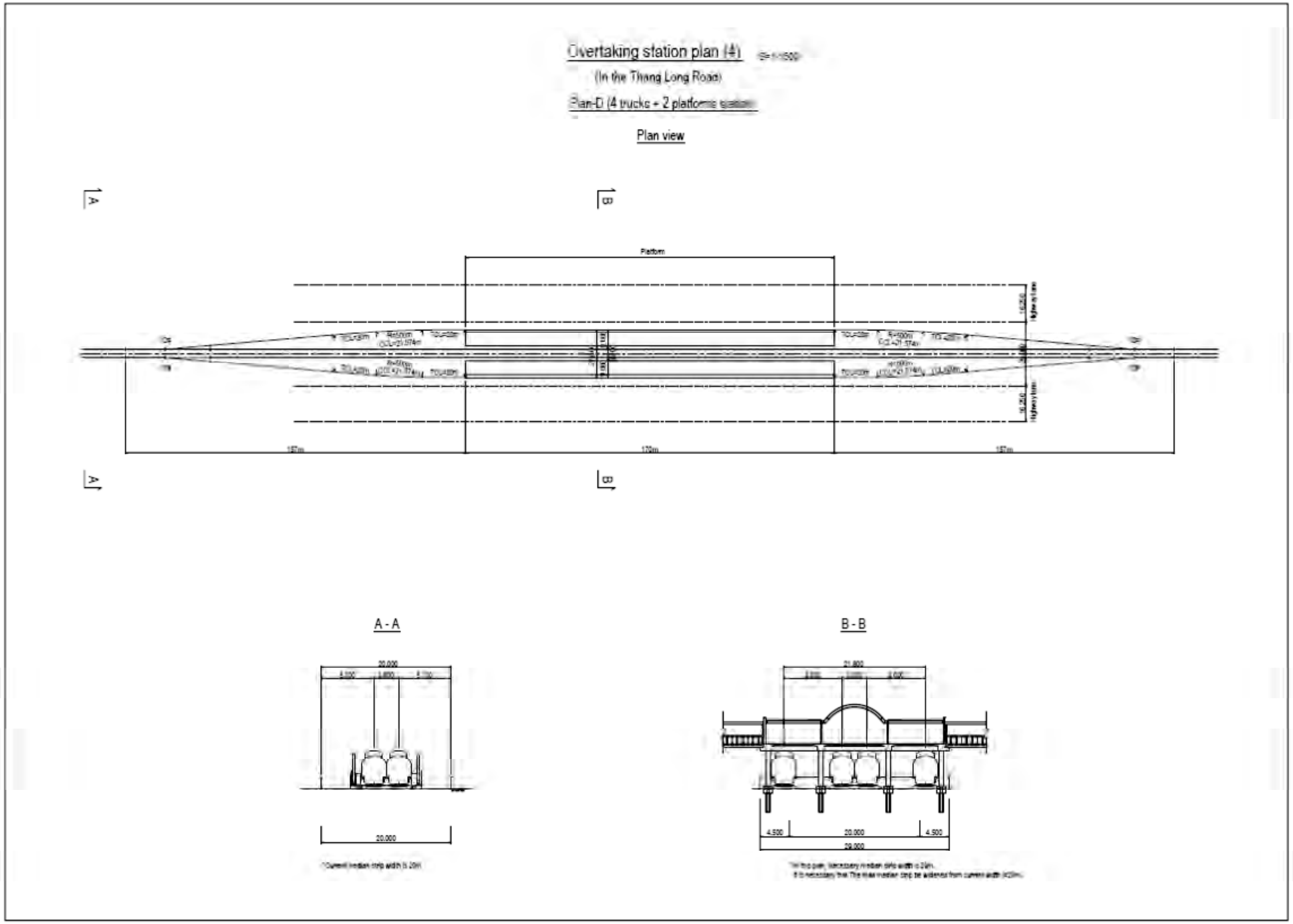


Figure 3.10.9 Study on passing track (4) Source: JICA Study Team

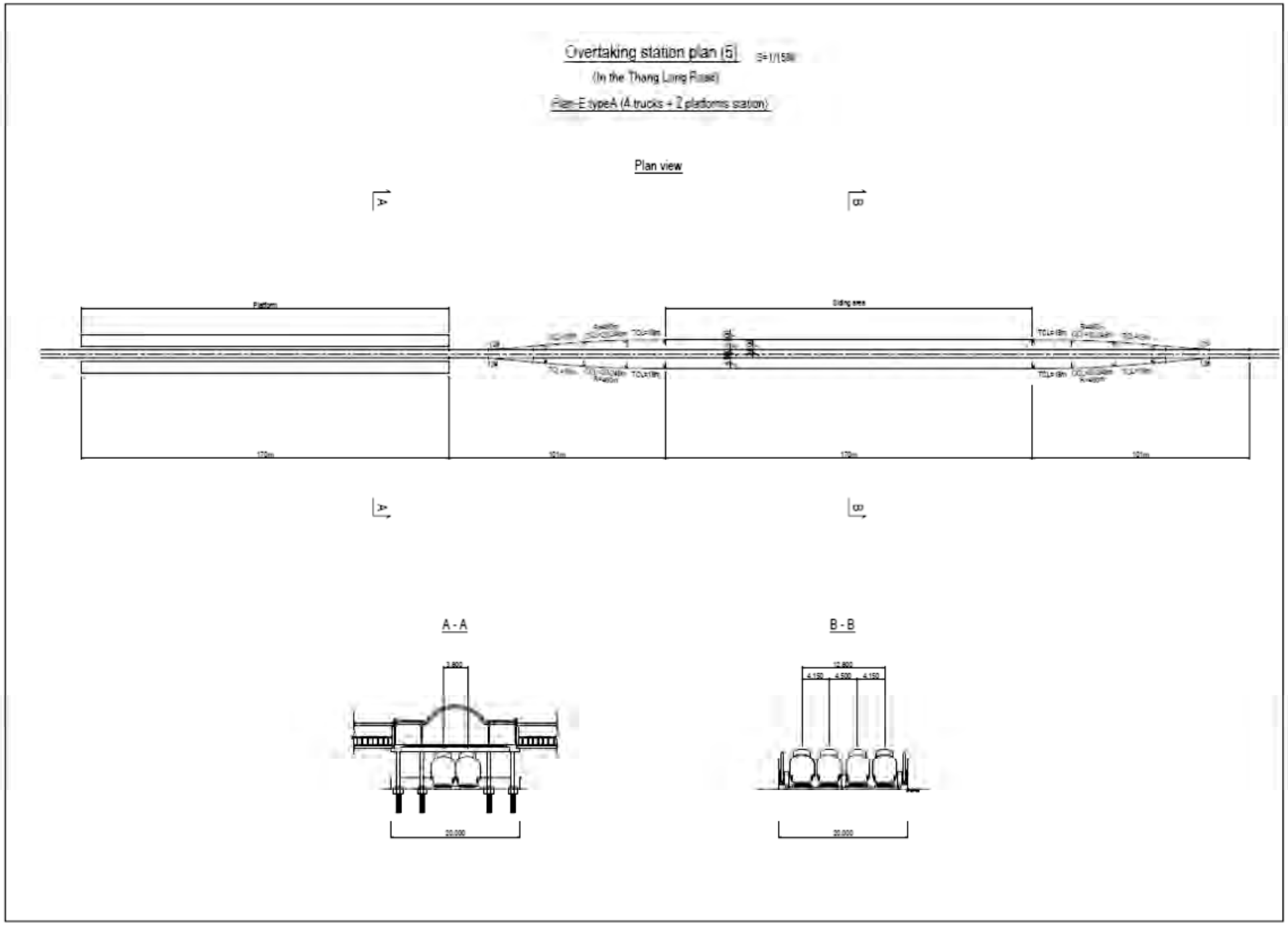


Figure 3.10.10 Study on passing track (5) Source: JICA Study Team

3.10.4 Study on the area near the ring road 2

As for the area near the ring road 2, it is indicated in the 3.4.7 (1). Detail drawings are shown as follows.

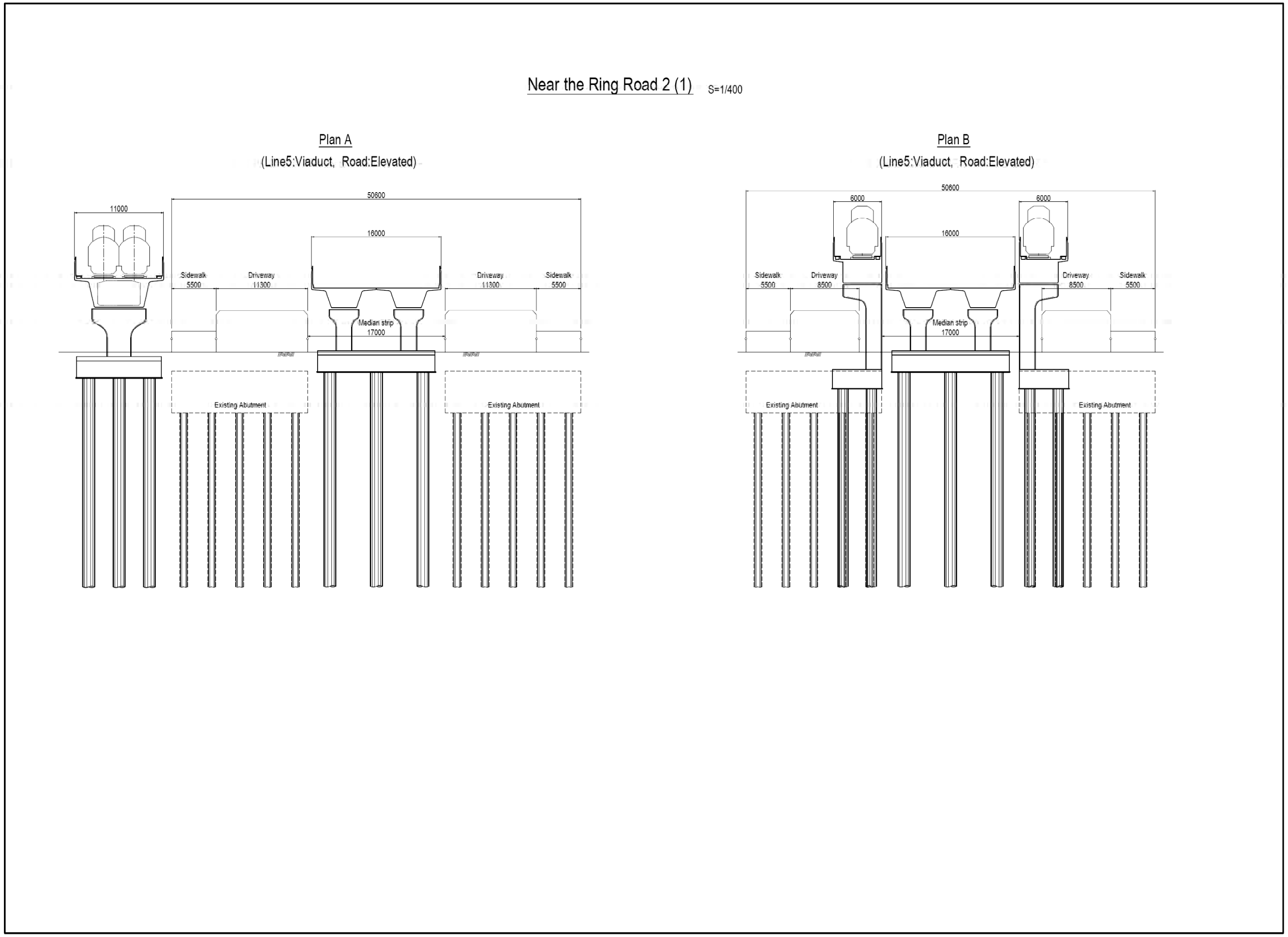


Figure 3.10.11 Study on the area near the ring road 2 (1) Source: JICA Study Team

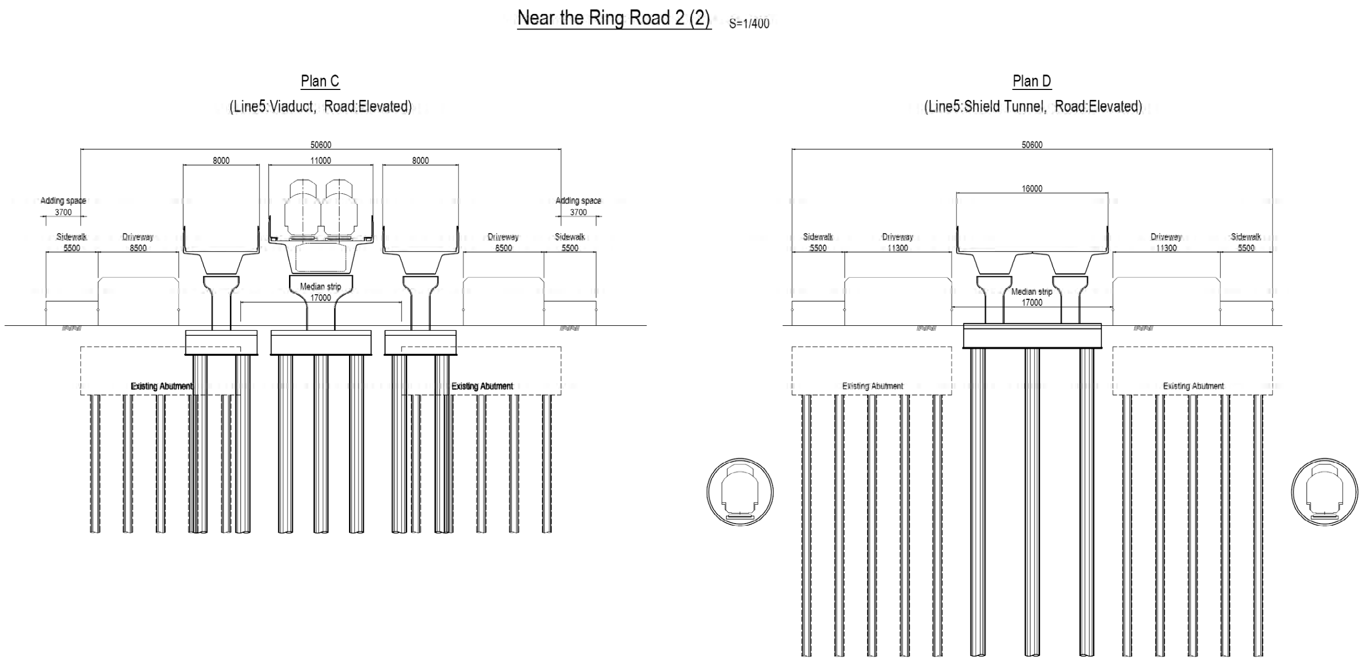


Figure 3.10.12 Study on the area near the ring road 2 (2) Source: JICA Study Team

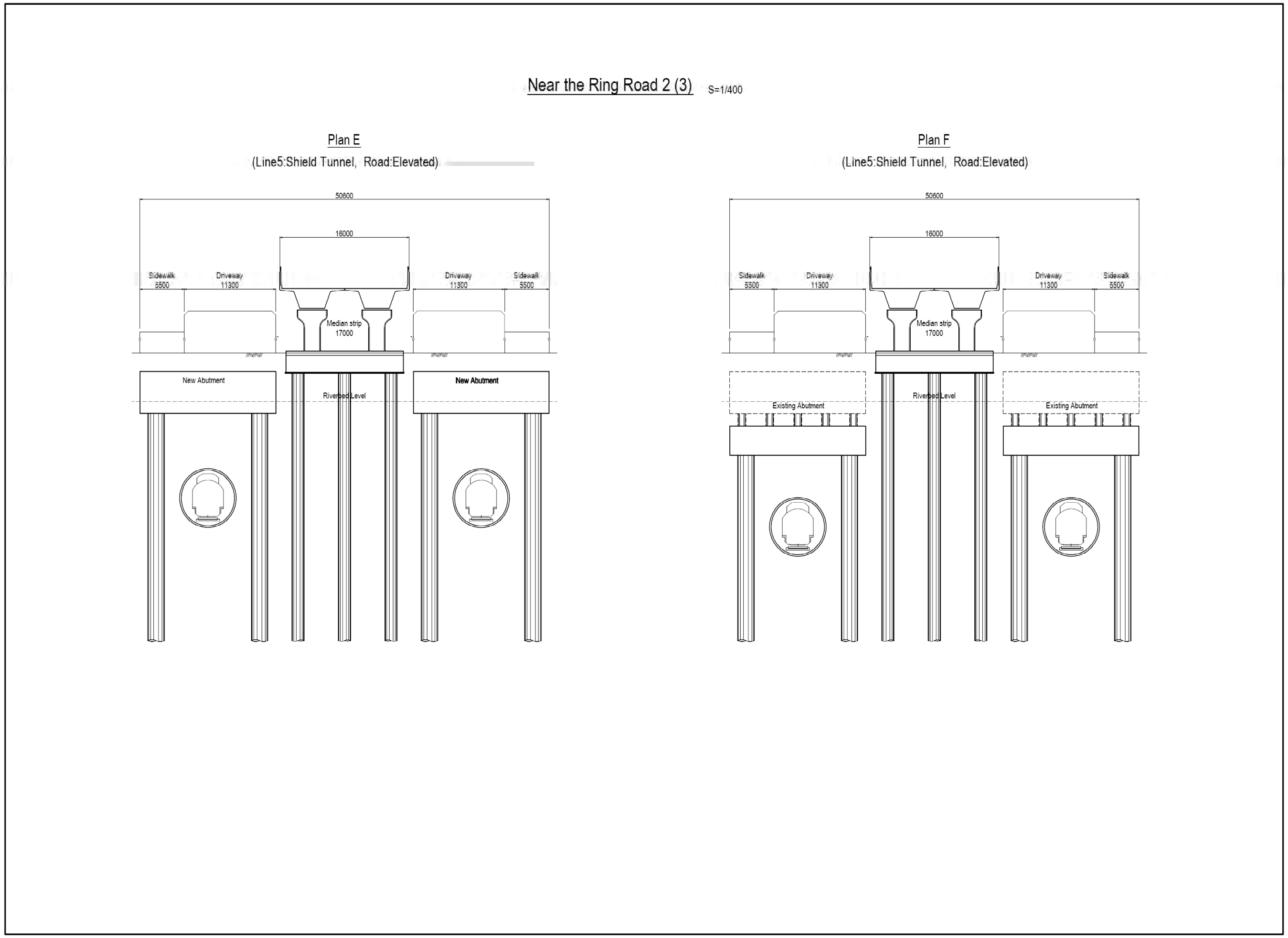


Figure 3.10.13 Study on the area near the ring road 2 (3)   Source: JICA Study Team

3.10.5 Study on the area near the ring road 3

As for the area near the ring road 3, it is indicated in the 3.4.7 (2). Detail drawings are shown as follows.

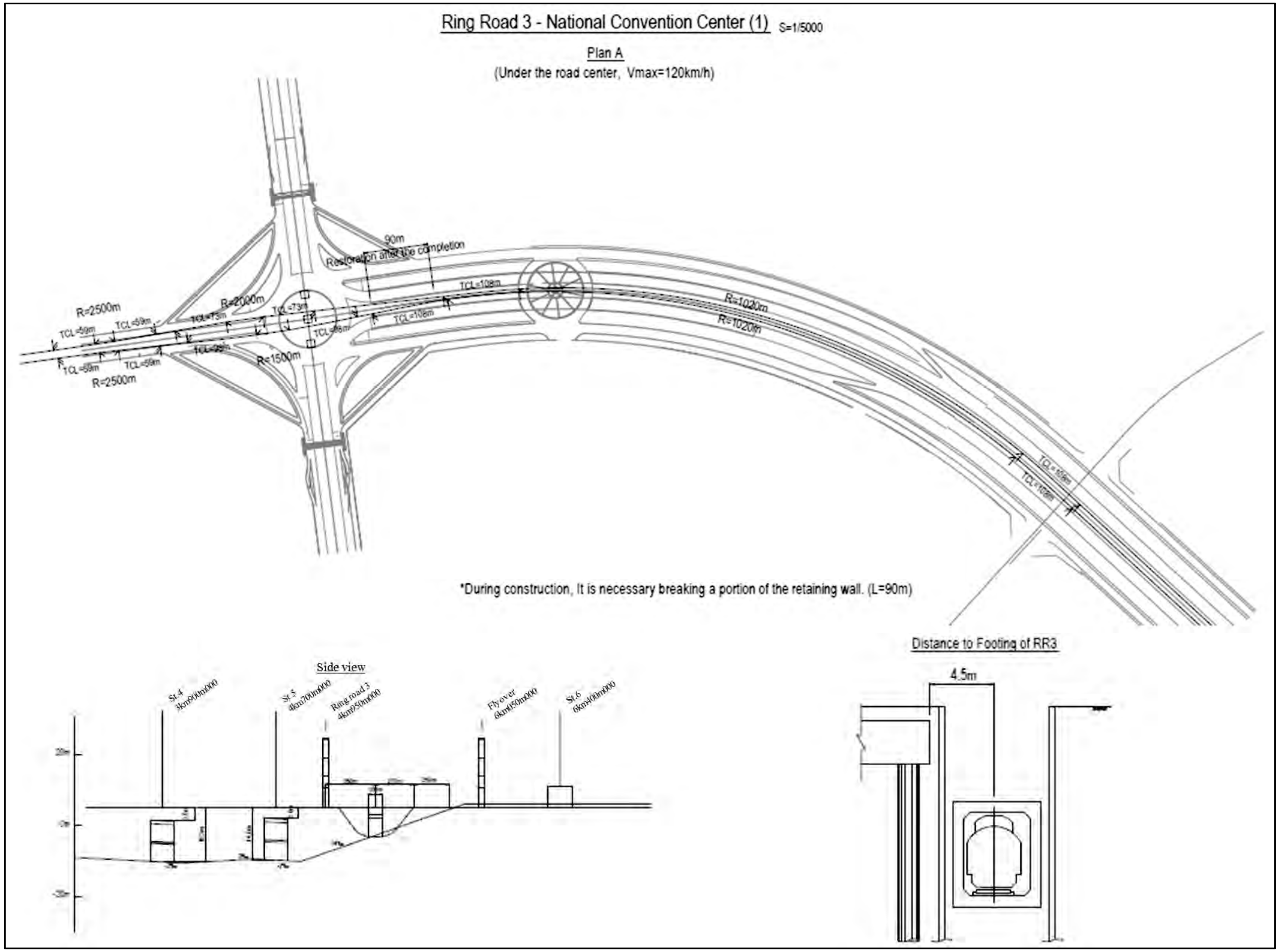


Figure 3.10.14 Study on the area near the ring road 3 (1) Source: JICA Study Team

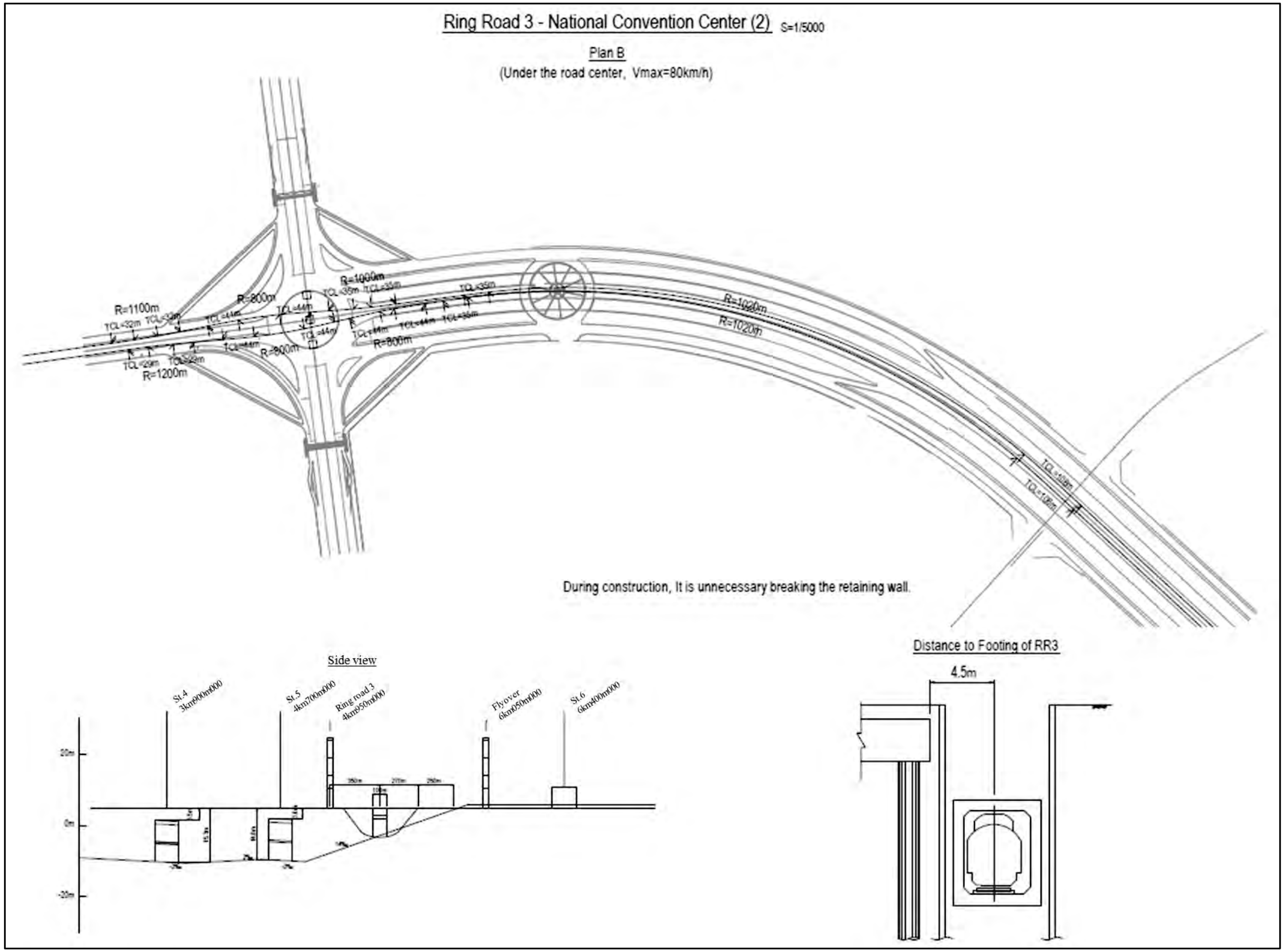


Figure 3.10.15 Study on the area near the ring road 3 (2) Source: JICA Study Team

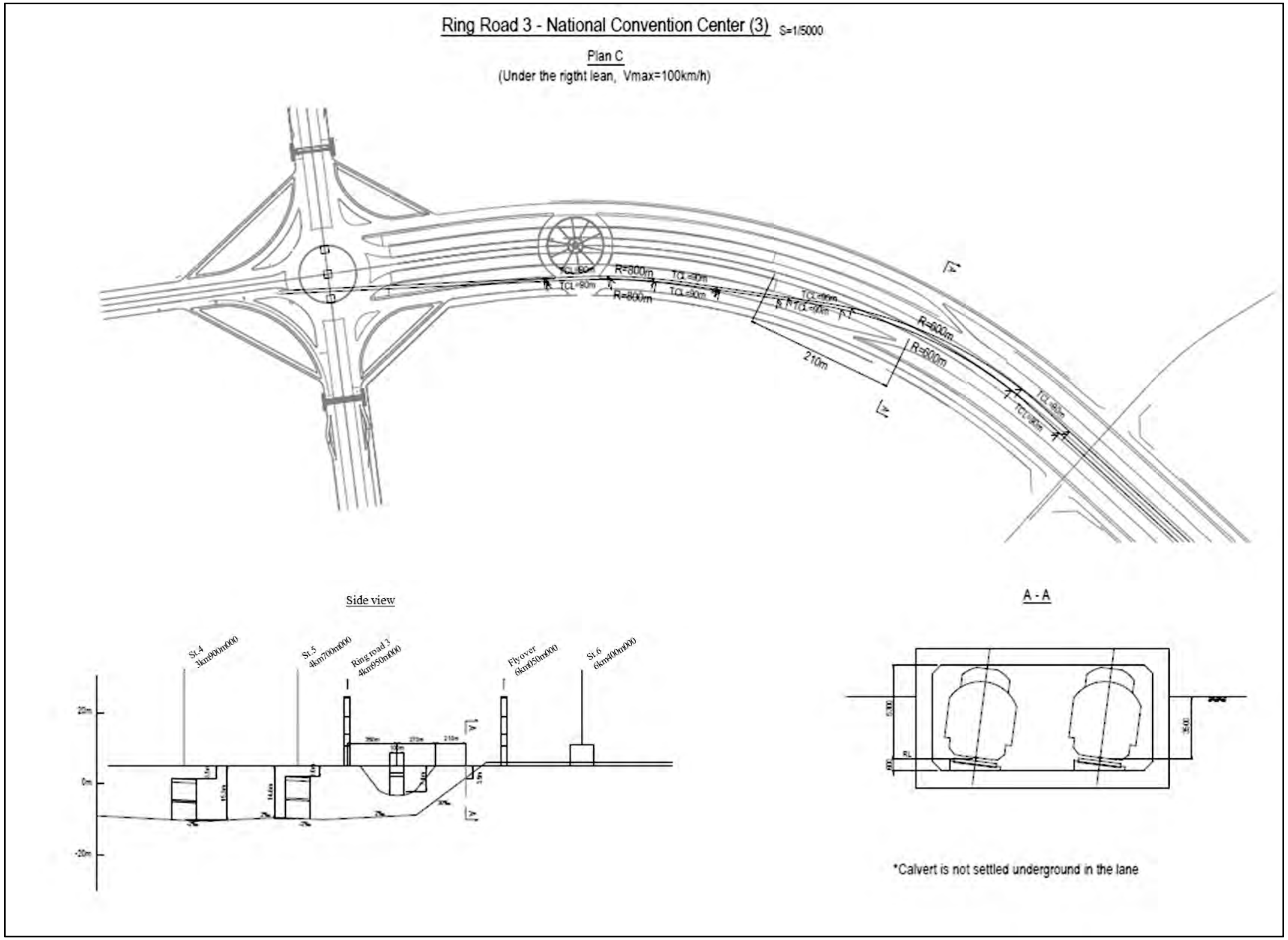


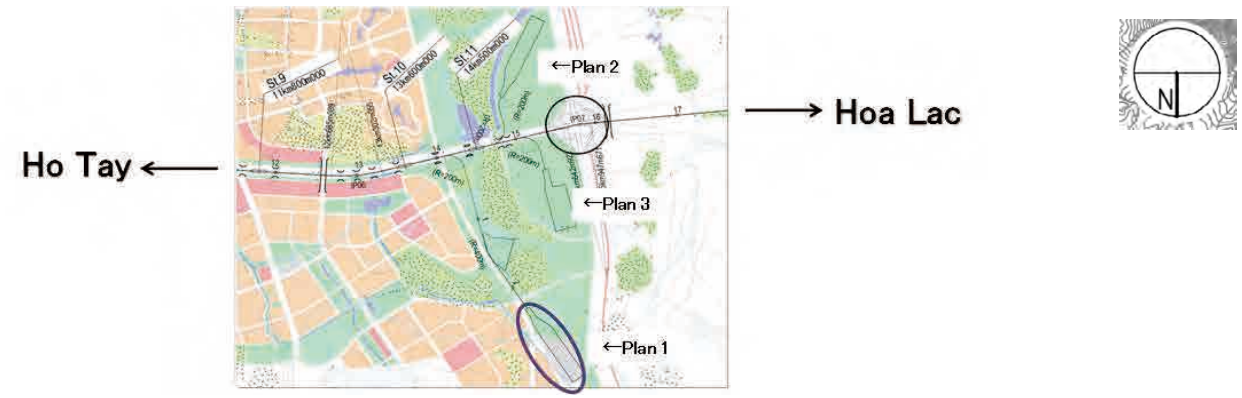
Figure 3.10.16 Study on the area near the ring road 3 (3) Source: JICA Study Team

3.10.6 Comparison of proposed sites for depot

Proposed site is shown in 3.1.2 (3). Here, the possibility of alternative plan of construction near St.10 was studied. Their results are shown as follows.

Table 3.10.7 Comparison of proposed sites for depo

<Position diagram>



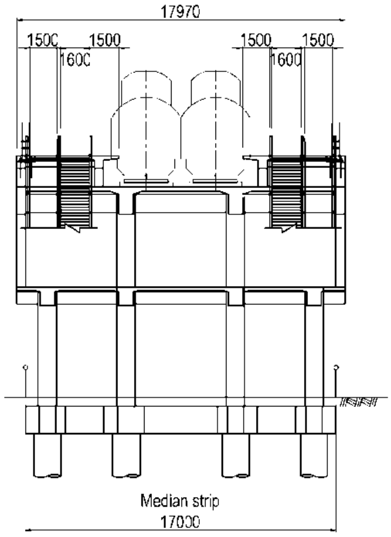
Plan	Plan 1	Plan 2	Plan 3	Notes
Outline	It is possible to construct new stations along the depot-in/depot-out line.	It is located at the north side of Thang Long road.	It is located at the north side of Thang Long road.	
Plan of development project	None	Exist	Exist	
Consistency with master plan	Matching with master plan It can be shared with Line 8.	Not matching with master plan	Not matching with master plan It can be shared with Line 8.	
Issues	・Progress of development projects near the depot ・Trend of demand for railway	・Revision of master plan ・Large-scale embankment is required. ・Landowners' intention	・Revision of master plan, ・Large-scale embankment is required. ・Landowners' intention	
Evaluation	There is no problem to acquire the land. Measures on environment can be conducted. It is necessary to examine whether the demand which is worth constructing new stations can be expected.	The expectation on operation is great as depot is close to the main line. It is necessary to examine the alignment of railway line and confirm with the landowner.	The expectation on operation is great as depot is close to the main line. It is necessary to examine the alignment of railway line and confirm with the landowner.	As for every plan, the width of road from Thang Long road to the depot site need be extended for developing depot site or carrying in rolling stocks.
	○	△	△	

Source: JICA Study Team

3.10.7 Alternative of elevated station

(1) Opposite 2 platforms/2 tracks, between the original point and the ring road 3

In this idea, as shown in Fig 3.10.17, the total width of two platforms and three tracks is a little larger than the width of the median strip.

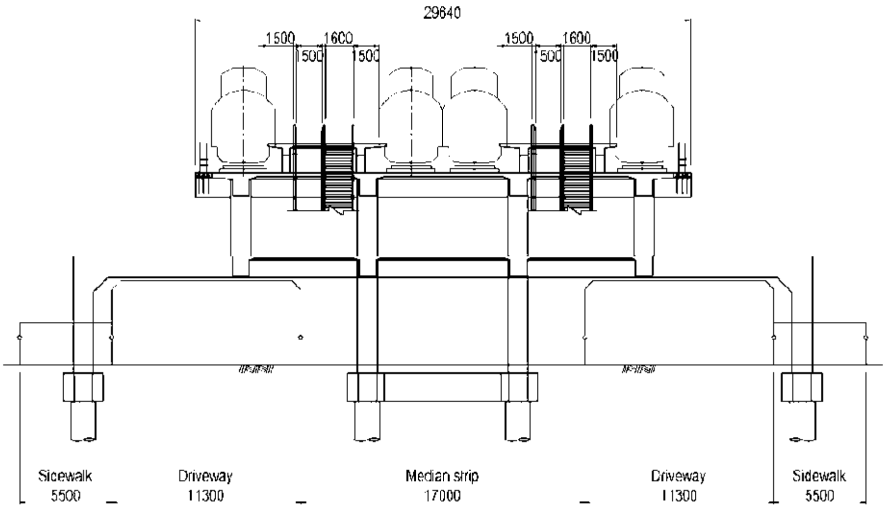


Source: JICA Study Team

Figure 3.10.17 Elevated station (2 opposite platforms/2 tracks)

(2) Island 2 platforms/4 tracks, between the original point and the ring road 3

In this idea, station structure is ideal since a train can variously connect with the other train. As shown in Fig 3.10.18, however, the total width of two platforms and four tracks is considerably larger than the width of the median strip. This requires overhang girders to support the outside tracks, which interfere with carriageways at construction and maintenance in the future. The spans may involve technical issues to be addressed in view of their approximate length of 20 m. It is thought that steel or composite structures shall be used in place of RC structures in this case. Moreover, as the girders pass over the road at 7 to 10 m intervals, attention shall be paid to preserve a good sight.

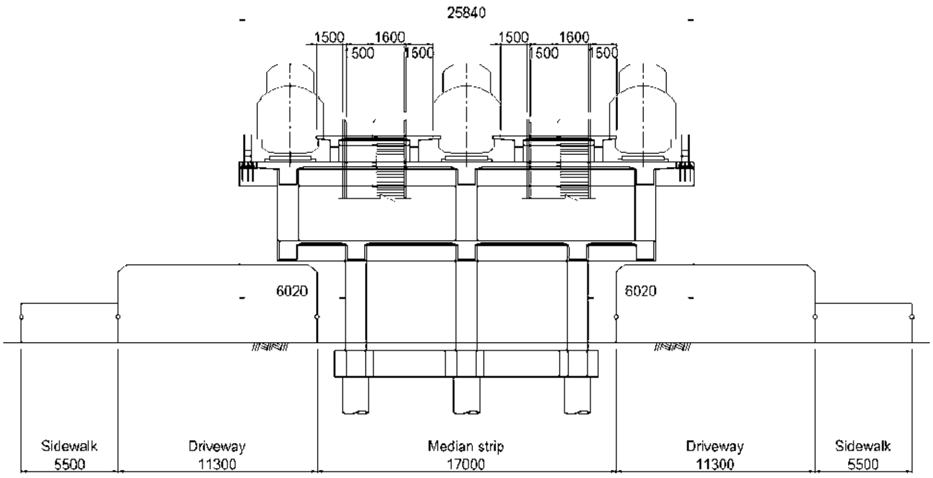


Source: JICA Study Team

Figure 3.10.18 Elevated station (2 platforms/4 tracks)

(3) Island 2 platforms/3 tracks, between the original point and the ring road 3

In this idea, even if demand far exceeds assumption at the Ho Tay station which is the original point, this type station can accommodate passengers satisfactorily. As shown in Fig 3.10.19, the total width of two platforms and four tracks is considerably larger than the width of the median strip. This requires overhang girders to support the outside tracks, which interfere with carriageways at construction and maintenance in the future. However, some issues about construction are existed. As the girders pass over the road at 7 to 10 m intervals, attention shall be paid to preserve a good sight.



Source: JICA Study Team

Figure 3.10.19 Elevated station (2 platforms/3 tracks)

3.10.8 Alternative plans of St.10

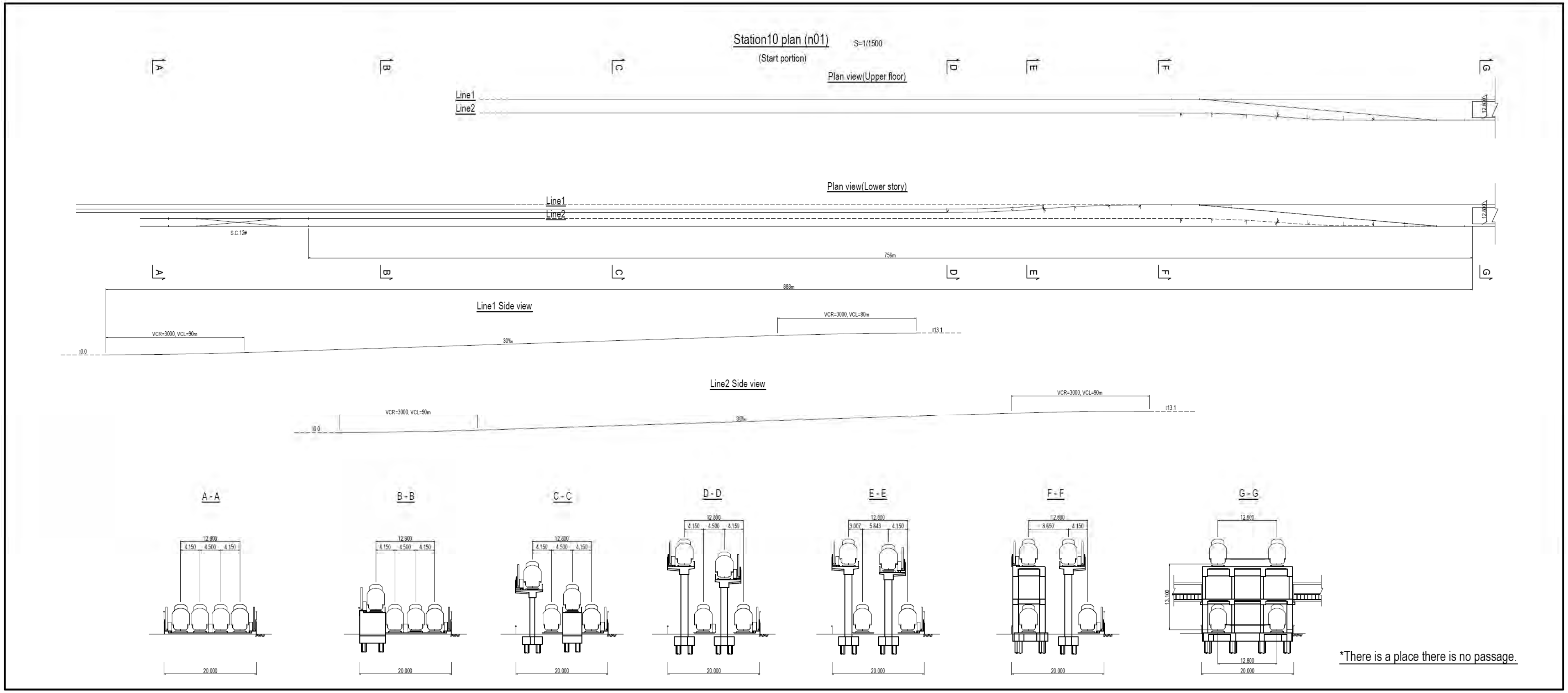
The route plan and station structure of Line 5 are as already mentioned in this Chapter, and especially regarding the matters considered to make flexible correspondence possible in the future, it is as mentioned in 3.4.9 "Proactive step plan in consideration of future work." As discussed in 3.4.9 (1) "When adding a station," however, in case more stations than planned will need to be constructed in the future, it is ideal to introduce over-taking stations by dividing trains into express and local ones. Nevertheless, as width of the median strip in the Thang Long road is very limited, ideal station structure has not been planned.

Therefore, alternative plans are shown as follows in order to solve this problem.

(1) In case Phase 2 is constructed, it becomes possible to construct stations for over taking and connecting from express trains to local ones.
(2) In case Line 8 is constructed, not only sharing of depot but operation plan coordinated with the Line 5 can be realized.

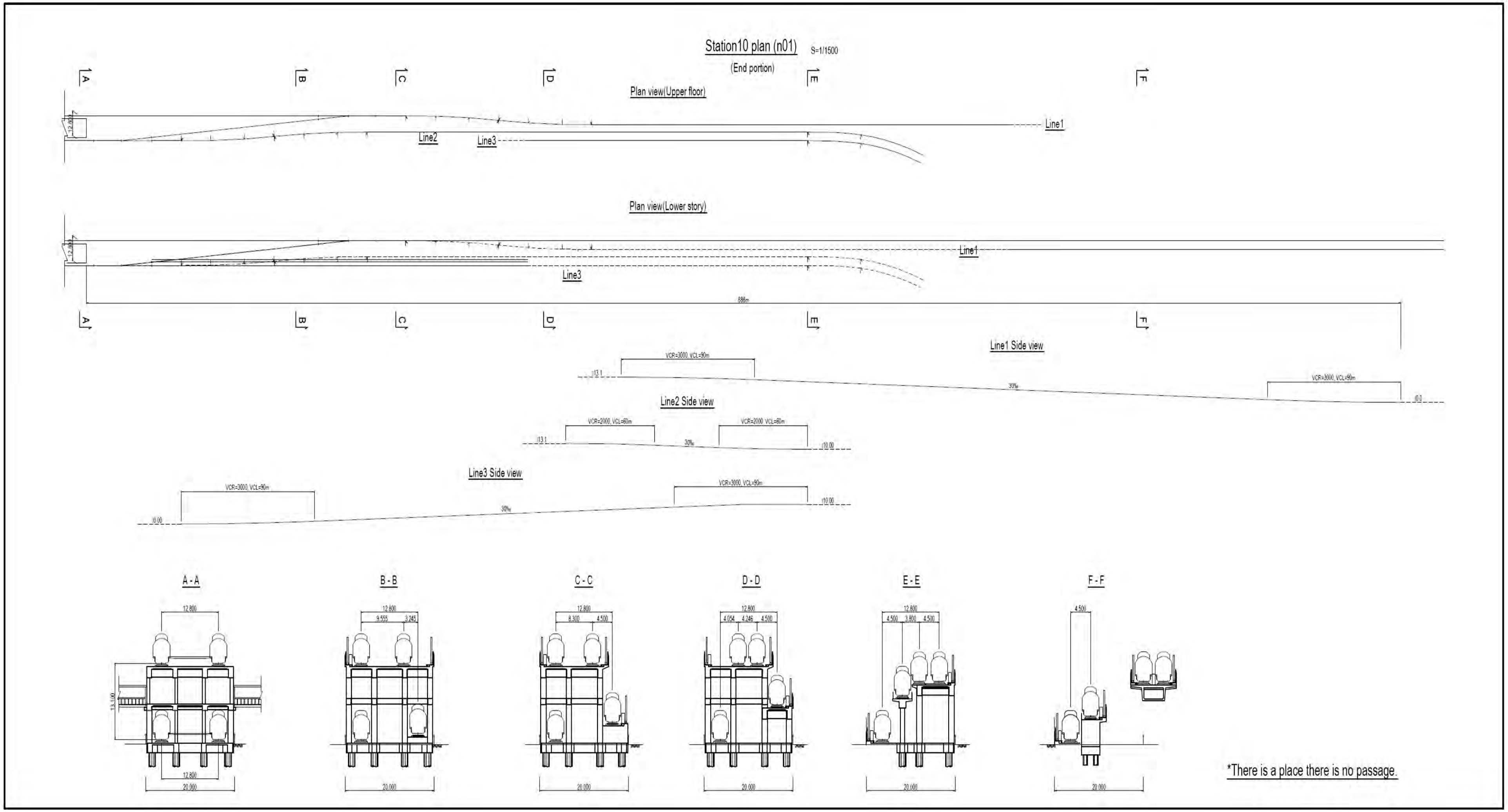
Outline of the alternative plans for St.10 is as follows, and planning diagrams are shown in Figures 3.10.20 and 3.10.21.

(1) It shall be elevated structure in order to construct station part in the median strip of the Thang Long road. (For detail design, it should be examined in detail whether the elevated structure would be surely installed in the median strip.)
(2) Depot-in/depot-out tracks shall be elevated structure, which enables the tracks to pass the Thang Long road.
(3) The track going to suburban area shall be constructed on the ground, and the one going to urban area shall be elevated.
(4) It is possible to construct shuttle line between Line 5 and Line 8 in the median strip of the Thang Long road.
(5) Passengers' accessibility to the station is similar to the original plan.
(6) Although construction cost increases approximately 200 million USD in comparison with the original plan, it is possible to construct an ideal station in suburban area.



Source: JICA Study Team

Figure 3.10.20 Alternative plans of St.10 (1 of 2)



Source: JICA Study Team

Figure 3.10.21 Alternative plans of St.10 (2 of 2)