Chapter 3 Adoption of Project Plan

3.1 Route selection

3.1.1 Basic issues in the route selection

Study Team has adopted line profiles to reflect the existing roads so that land acquisition for railway construction is minimized as far as possible. A prerequisite is to guarantee the convenience of users and create pedestrian spaces at the nods between roads and railway stations. Study Team has formed construction plans around stations to facilitate smooth transfer between different traffic modes. In regard to the structure style, Study Team proposed a plan that paid attention to the landscapes that match with the development of Hanoi city in the future and those to cut the total cost including the cost for construction and maintenance of facilities. Therefore, it is proposed that the route selection will be the one to facilitate project promotion from the viewpoints of cost and implementation of construction work and yield various merits from an early stage.

In view of the fact that the line passes the city center, Study Team will construct stations at the crossing points with other transport modes to establish railway network and ensure the convenience of users, while limiting the station-to-station distance to 1,500 m or less in the midtown area. The location of stations in suburban areas will be determined in consideration of land utilization plans and natural conditions.

To cut the travel time and maintenance cost, Study Team guarantees as appropriate line profiles as possible avoiding level crossings and minimizes curved sections, thereby aiming at raising the security level of train operation and rapidity between the city center and suburban areas to be connected in about 30 minutes.

Furthermore, the construction plan will be divided into phases 1 and 2, to extend the total length step by step to cope with the development of the Hanoi city and surrounding areas and increases in the users of railway transport.

(1) Overall route plan

Up to the ring road 3 from the starting point, railway structures are supposed to be constructed between the Van Cao street and the Tran Duy Hung street. The existing roads are constructed to a broad width including median strips, which are large enough to secure the lands for railway viaduct construction. As the median strips are constructed in consideration of the importance of greening and beauty of landscape, construction of motorbike parking lots and other provisions are thought to be important under viaducts to accelerate the modal shift to public traffic means as well as the succession of the current considerations to landscapes. Therefore, a sight respecting plan including planting in the layout shall be promoted.

To cut the project cost, rails will be laid on the ground from the vicinity of the ring road 3 to the national conference hall on the terminal side of the line, except at some places where viaducts are required to pass over the existing VNR line or car port approach roads. However, the length of viaducts will be minimized as far as possible to cut the construction cost.

(2) Phased construction of the Line 5

For realization of the master plan of the Hanoi city urban railway, it is important to promote effective investment by minimizing government debt. Since the Line 5 is the line which connects the central area of the Hanoi city where improvement of road environment is prioritized and suburban section where future development is expected, Study Team proposes the construction of railway in two phases by antecedently opening the section where demand for the Line 5 is highly expected.

Land development of suburban section along the railroad line is expected to be positively conducted by private companies by giving opportunities for Hanoi citizens to utilize railway and experience its convenience and comfortability and by enhancing the value of the Line 5. Moreover, it is expected to decrease government debt by introducing private funds to the one portion of construction cost of stations in Phase 2.

<Phase 1> Ho Tay to An Khanh 14.1 km

- Improvement of saturated road transportation environment in urban area (promotion of public transportation use and improvement of the environment)
- Establishment of urban transportation network in urban area
- Access improvement from the line to the residential area around Song Phuong
- Improvement of development in suburban area along the railroad line
- Transportation of feeder bus in the stations beyond An Khanh

<Phase 2> An Khanh to Ba Vi 24.3 km

- Extension of the line with the progress of development in Hoa Lac
  (improvement of connection between urban area and Hoa Lac)
- Promotion of land development in suburban area outside of the ring road 4

■Consideration after receiving results of demand forecast

- As indicated in Chapter 2.3, in Hanoi city, zones with much amount of generation tend to expand in the suburban part. The zones with many amount of generation will be concentrating to the southwest part including Hoa Lac, northern part and southeast part in 2030, and it is estimated that the amount of generation will expand annually with more than 10% increase rate. By constructing railway in proportion to the expansion of generated traffic volume, the multipulier effect in promotion of development in Hoa lac and the area along the railroad and increase in population in the area along the railroad can be anticipated.
- The predicted value of maximum demand during peak hours in Phase 2 section (An Khanh to Ba Vi) in 2029 is 4,934 (person/hour). Meanwhile, transportation capacity of a bus is approximately 5,000 (person/hour). Therefore, even if it is not train transportation system in 2029, transportation by buses is within the realms of possibility to cope with the demand value. In addition, as Thang Long highway has three lanes in each direction even only main lane and the basic traffic capacity is 6,600pcu/h in terms of passenger cars; therefore, it still has enough space on the road for saturation even if additional sixty buses (per hour) are operated.
- In 2030, the predicted value of maximum demand during peak hours in Phase 2 section (An Khanh to Ba Vi) is 6,481 (person/hour), and transportation by bus becomes difficult.

■Consideration after receiving results of financial analysis

The aggregate amount of cash flow (by 2053) of the Railway project implementing body (Vietnamese government) that manages the railway business is calculated. And two cases are compared: 1) constructing Phase 1 section in 2021 and Phase 2 section in 2030, and 2) constructing whole line (both Phase 1 and Phase 2 sections) at one time in 2021. Margin of negative value becomes almost double since railway construction at one time will lead to the burden of an enormous initial investment and operating expenses compared to the scale of demand.

The result suggests that it is desirable to take an approach of constructing the Phase 2 section in stages rather than constructing railway in developing suburban area in the early stage.

As the result of above examination, there is no need to rush construction of railway infrastructure which requires a large investment, and transportation by bus is appropriate until 2030 when road transport can correspond to demand. In addition, concerning construction schedule, it is reasonable to decide in consideration of situation of development along the railroad, the growth rate of population, and situation of utilizing railway by citizens of Hanoi city.

(3) Plans for stations

For stations and surrounding areas, it is required to create spaces to take into account the line of flow of pedestrians to weigh safety, comfort and convenience. As the communication between stations and surrounding areas shall be positioned from the viewpoint of constructing communities, bird’s-eye view discussions shall be made over the total areas.

In the route selection, large-scale commercial facilities and those attracting a great number of people will be constructed around the stations located in the midtown areas (on the starting side of the ring road 3). Therefore, the communication between stations and surrounding areas is extremely important. From the viewpoint of traffic nodes as the role of the stations as well, it is important to affect an oneness feeling of midtown areas. Therefore, pedestrian spaces shall be created while taking note on the following points.

1) Guarantee of safety
2) A feeling of oneness with surrounding town areas
3) Smooth and convenient interchange with other railways
4) Provisions to accelerate modal shift such as motorbike parking lots
5) Communication with buses and other transport means
6) Universal design friendly with the aged people
7) Creation of a comfortable pedestrian space even in rain
8) A space with excellence of both maintenance of signs and transmission of information

In concrete terms, the stations on the starting point side of the ring road 3 in the midtown area will be placed to construct a railway network to enable smooth interchange with other lines. Therefore, Study Team proposes a layout of each station that serves the purpose. The communication pass for interchange shall be constructed to ensure a convenient and comfortable space as a traffic node and induce a great volume of public traffic demand.

Furthermore, provisions shall be made to make the line profile, distribution of stations and design of the line enable interchange with the Lines 6, 7 and 8, in case they are planned in the suburbs (terminal side of the ring road 3)

Study Team has discussed measures to ensure smooth access to commercial facilities and residences in the surrounding areas and utilization of station plazas and under-viaduct spaces in consideration of nodes to buses, taxis, motorbikes and other traffic means. Through these measures, Study Team will accelerate the modal shift from motorbikes and expect the merits to cut travel time by users and improve the environment from the viewpoint to expedite utilization of public traffic. These measures further improve the value of surrounding areas and change the image of the whole line to realize a model railway line for the development of the Hanoi city.

Here, a whole plan which becomes base in studying a route was summarized. Basics of railway plan outline route map and summary of railway line layout are shown in Table 3.1.1, Fig 3.1.1 and Fig 3.1.2. However, in formulating railway basic plan, the plan shall conform to Vietnamese standard. The plan shall be also considered about collaboration with Line 2.

Table 3.1.1 Basics of railway plan

Item		Description
Line	Operating section	Starting point: Ho Tay Terminal: (phase 1) An Khanh (phase 2) Ba vi
	Length for revenue service	38.2 km, double-track
	No. of stations	(phase 1) 10, (phase 2) 7
	Length of construction	40.7 km, double-track (including depot-in and depot-out tracks) Length of main track 38.4 km + Length of depot-in and depot-out tracks 2.3 km
	Area of depot	Approx. 17 ha
Operation & rolling stocks	No. of cars in a train-set	(Phase 1) 4 at start (2M2T): 44 cars in total (Phase 2) 6 (3M3T): 90 cars in total It is possible to increase cars per train set up to 8 depending on demand.
	Passenger capacity	Leading car: 161 people Middle car: 183 people
	Rolling stock	Length: 20,000 mm, Width: 2,950 mm
	Maximum train operating speed	120 km/h for elevated and ground-level sections (80 km/h for underground section)
	Minimum travel time	(Phase 1) St.1-St.10 18 minutes 30 seconds (Phase 2) St.1 to St.17 41 minutes
	Operating method	ATC One-man operation (ATO/ATP)
Specifications	Gauge	1,435 mm
	Rail	50 kg N rail or 60 kg rail
	Turnout	Main line #12, depot #8
	Axle load	14 ton
	Maximum gradient	35‰ or less in design
	Minimum curve	Main line: 800 m, depot siding: 200 m
	Vertical curve	3,000 m
Electricity	Voltage	DC 1,500V
	Current collecting system	Simple catenary
	No. of substations	7
Safety facilities	Route control	Train operation control system
	Train detection	CBTC + track circuit (inside depot, backup)
	Block system	Moving block
	Train radio	Duplex digital radio, LCX
Station facilities	Movable platform gates, elevator, escalator, CCTV, automatic fare collection devices, multifunctional toilet	

Source: JICA Study Team

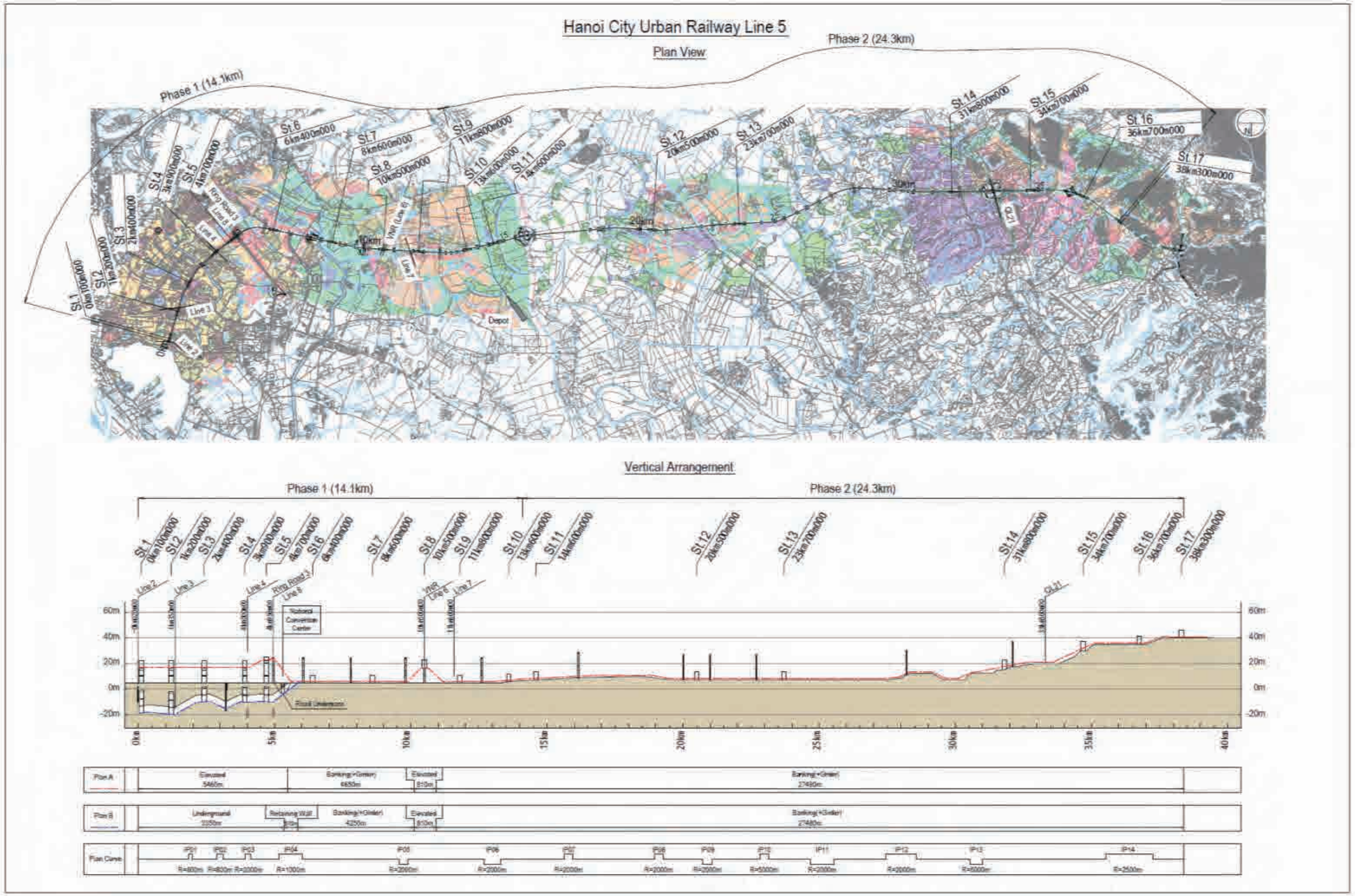


Figure 3.1.1 Outline of route map

Source: JICA Study Team

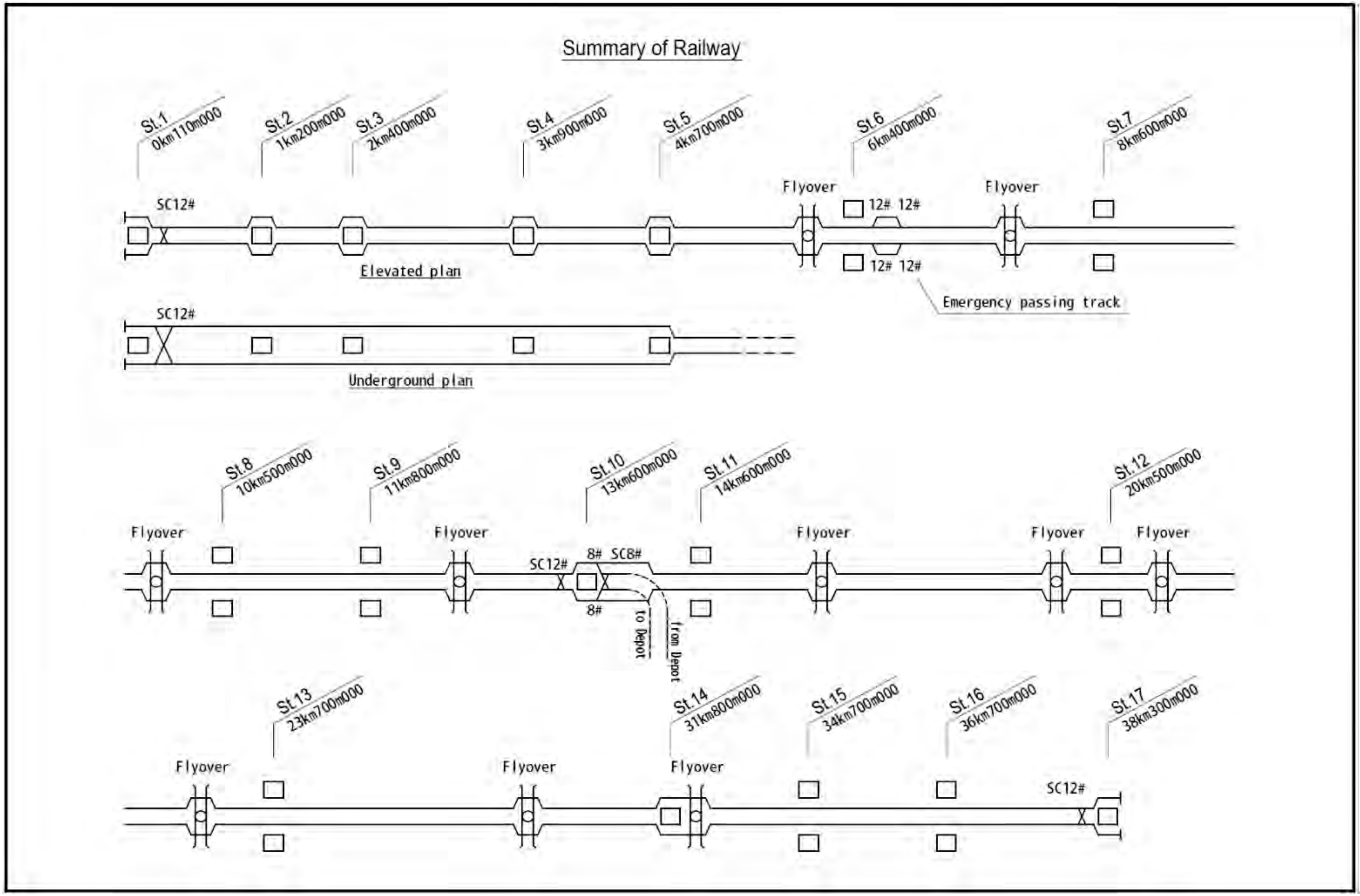


Figure 3.1.2 Summary of railway line layout Source: JICA Study Team

3.1.2 Discussions on the route selection

In this survey, Study Team regards the 38 km-long route from the southern shore of the West Lake (Ho Tay) to Ba Vi at the western part of the Hanoi city as the planned line, which is in principle confined within the existing road to minimize the necessity of land acquisition. Moreover, the places of depots are also discussed and compared with other alternatives.

(1) Current situation

The field survey along Line 5 was carried out. After conditions of the land use were summarized by the survey results and the existing datum, checking the route of Line 5, layout planning of the stations was performed. Moreover, basic materials for determination of layout planning and construction style of the stations shall be created.

1) Place of St.1 (0 k 000 m)

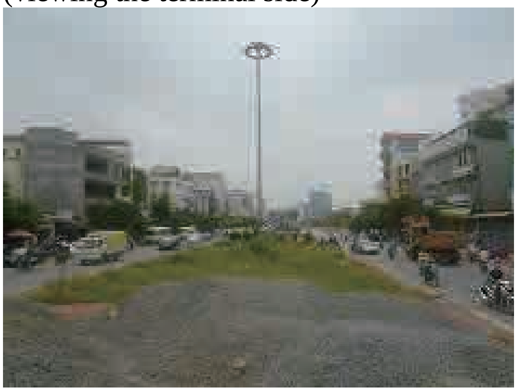
This station will be a junction to the St.5 of the urban railway Line 2. The road (50 m in width) is composed of a frontage (about 5.5 m) and two lanes (about 11 m) on one side, a median strip (about 17 m) at the center and another set of frontage and two lanes on the other side.

Source: JICA Study Team

Figure 3.1.3 Place of the starting point (viewing the terminal side)

Source: JICA Study Team

Figure 3.1.4 Place of the starting point (viewing the starting point side)



Source: JICA Study Team

Figure 3.1.5 Place of the starting point (position of the planned St.1)

2) Place of St.2 (1k 200m)

This station will be a junction to the St.9 of the urban railway Line 3. The median strip is rather wide (about 17m) from the starting point to this point, which tapers to about 2.9m toward the terminal side.

Source: JICA Study Team

Figure 3.1.6 Place of the crossing point with the Line 3
(position of the planned St.2)

Source: JICA Study Team

Figure 3.1.7 Place of the Embassy of Japan
(position of the planned St.2)

Source: JICA Study Team

Figure 3.1.8 A scene of the surrounding facilities
(position of the planned St.2)

The Embassy of Japan and an international school are located near this point, with LOTTE Mart and other commercial facilities under construction.

3) St.2 to St.3 (1k 400m to 1k 800m) section

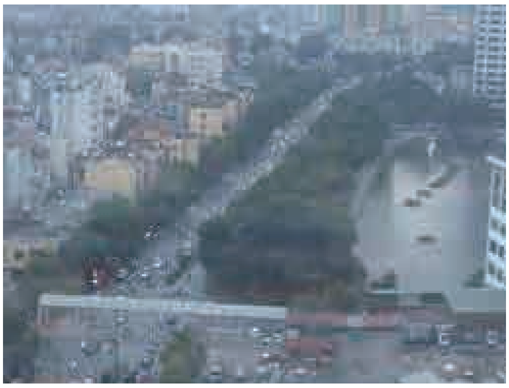
On the one hand, there is a lake on the west, and the median strip (about 2.9 m wide) in this section is smaller than in other sections. It needs to be examined in detail, therefore, to construct wall type bridge piers within the median strip in this section (as the width of the wall type bridge pier skeleton is larger than 2.0 m).

On the other hand, the width of the frontage facing the lake on the right-hand side is large. Considering the construction of road components, the total width of the road seems to be the same as that in other sections where the median strip is larger (still need deliberate survey and study).

From the above information, the bridge piers of the Line 5 may be (1) the wall construction type with the widened median strip or (2) the gate type to set one pier in the median strip and the other in the right-hand side frontage.

Source: JICA Study Team

Figure 3.1.9 Crossing point with Line 3 (1k 400m)

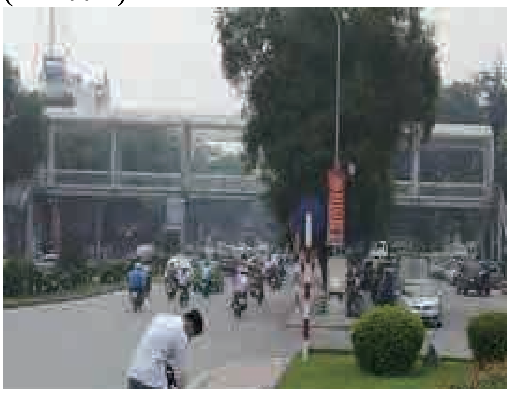


Source: JICA Study Team

Figure 3.1.10 Place of smaller median strip (1k 400m)

Source: JICA Study Team

Figure 3.1.11 Crossing point with Line 3 (1k 400m)



Source: JICA Study Team

Figure 3.1.12 Road construction facing west (1k 400m)

Source: JICA Study Team

Figure 3.1.13 Carriageway facing west (1k 400m)

Source: JICA Study Team

Figure 3.1.14 Road construction at the place of smaller median strip

Source: JICA Study Team

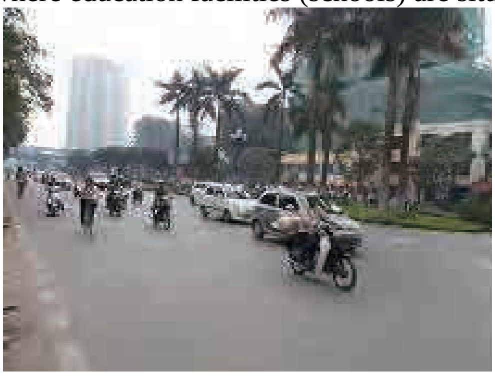
Figure 3.1.15 Road construction at the place of smaller median strip (1k 500m)

Source: JICA Study Team

Figure 3.1.16 Place where relocation is required (1k 800m)

4) Place of St.3 (2k 500m)

The St.3 is planned approximately at the center between St.2 (1k 200m) and St.4 (3k 800m), where education facilities (schools) are situated.



Source: JICA Study Team

Figure 3.1.17 Place where the St. 3 is planned (2k 500m)

5) St.3 - St.4 section (3k 200m)

This is a river crossing the Line 5, having a width of about 30m (100m including the revetments and frontage roads). The Line 5 requires a bridge, about 100m in length, to cross the river. It is necessary to discuss the structure form of bridge pier.

Source: JICA Study Team

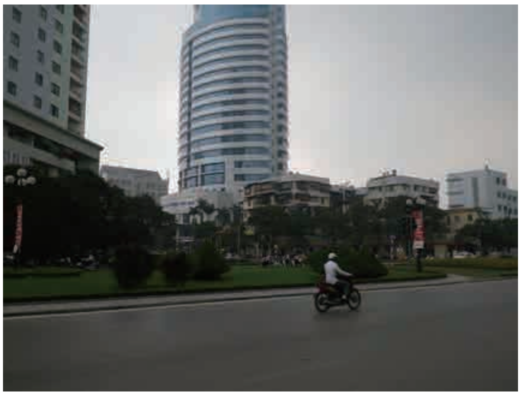
Figure 3.1.18 A river crossing the Line 5 at the 3k 200m point

Source: JICA Study Team

Figure 3.1.19 A river crossing the Line 5 at the 3k 200m point

6) Place of St.4 (3k 900m)

This place is close to the crossing point with the urban railway Line 4. Interchanging means will be discussed. Commercial facilities built in recent large-scale development projects are seen on the terminal side of this point.



Source: JICA Study Team

Figure 3.1.20 Place where the St. 4 is planne (3k 900m)

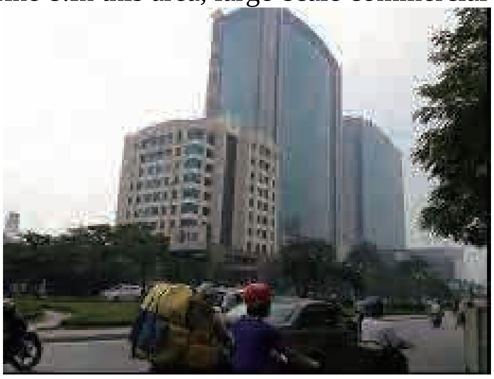
Source: JICA Study Team

Figure 3.1.21 Place where the St. 4 is planned (3k 900m)

7) Place of St.5 (4k 600m)

This place is close to the crossing point with the urban railway Line 8. Interchanging means will be discussed. As the grade separation work is under way for the ring road 3, it is thought that the urban railway Line 8 will be laid as an underground structure.

In case the Line 5 is elevated, it will pass over the ring road 3 to make a control point in vertical alignment of railroad line. In case the Line 5 passes underground on the other hand, it is required to pay attention to the bridge pier arrangement for the ring road 3, and crossing with Line 8.In this area, large-scale commercial facilities exist, such as Big-C and Grand Plaza.



Source: JICA Study Team

Figure 3.1.22 Place where the St.5 is planned (4 k 600 m)

Source: JICA Study Team

Figure 3.1.23 Place where the St.5 is planned (4 k 600 m)

8) Place of St.6 (6 k 600 m)

In the area near the planned station, construction work of commercial facilities and apparent office buildings is under way. An urban area exists on the north side of this developing place.

Source: JICA Study Team

Figure 3.1.24 Place where the St.6 is planned (6k 600m)

Source: JICA Study Team

Figure 3.1.25 Place where the St.6 is planned (6k 600m)

Source: JICA Study Team

Figure 3.1.26 Place where the St.6 is planned(6k 600m)

Source: JICA Study Team

Figure 3.1.27 Place where the St.6 is planned (6k 600m)

9) Place of St.7 (8k 400m)

The St.7 is planned approximately at the center between the St. 6 (6k 600m) and St.8 (10k 500m). At present, the area near the planned station site is not urbanized. The area on south side is dotted with the houses. Old cities can be seen at the north side of track of the place where distance is a kilometer away from the St.7.

Source: JICA Study Team

Figure 3.1.28 Place where the St.7 is planned (8k 400m)

Source: JICA Study Team

Figure 3.1.29 Place where distance is a kilometer away from the St.7(7k 400m)

10) Place of St.8 (10k 500m)

The road crosses a freight line of Vietnam National Railway (VNR), which is planned as the urban railway Line 6 for electrification and laying double tracks in the future. On the other hand, the expressway is planned as an underpass structure for grade separation with the crossing VNR line. In the expressway sections on both sides of this place, there are median strips, but no spaces between carriageways and frontage roads.

Source: JICA Study Team

Figure 3.1.30 Crossing with a VNR line (10k 500m)

Source: JICA Study Team

Figure 3.1.31 Crossing with a VNR line (10k 500m)

11) Place of St.9 (11k 800m)

This place is close to the crossing point with the urban railway Line 7. The wayside areas are under development, where a number of condominiums and houses are being built and a theme park is open on the south.

Source: JICA Study Team

Figure 3.1.32 Development on the south of St.9 (11k 800m)

Source: JICA Study Team

Figure 3.1.33 Development on the south of St.9 (11k 800m)

12) Place of St.10 (13k 600m)

The St. 10 makes a branching point to the depot to be constructed around the 14k 100m point.

13) St.11 - St.12 section (18k 500m)

The expressway crossing a wide river at this point has 8- span continuous PCT type girders at a length of about 240m (30m x 8). Like the expressway, a long bridge shall also be used for the Line 5 to cross the river.

Source: JICA Study Team

Figure 3.1.34 A river at the 18k 500m point

14) Places of St.12, St.13 (20k 500m, 23k 700m)

As the center of Quoc Oai, this place is surrounded with an eco-town having an area of about 2,000 ha extending to the Ta Tich bank and will be developed on the south along Thang Long road.

The existing town of Quoc Oai will be restructured to have the functions to provide general services, support the consumption of indigenous agricultural products and handicrafts, solve the unemployment problem in the area, develop ecological services and preserve historic landscapes and green belt corridors. The population in the future is expected to be 30,000 to 50,000.

Source: JICA Study Team

Figure 3.1.35 A scene at the place of St.12, St.13 (22k 100m)

Source: JICA Study Team

Figure 3.1.36 A scene at the place of St.12, St.13 (22k 100m)

15) Place of St.14 (31k 800m)

Hanoi city is now developing as a park called the Hoa Lac High-Tech Park having an area of 1,586 ha. It is scheduled to relocate the Hanoi Campus, Vietnam National University, to the west of the Park.

The station shall be located near the main gate of the Hoa Lac High-Tech Park.

Source: JICA Study Team

Figure 3.1.37 A scene at the place of the St.14 (31k 800m)

Source: JICA Study Team

Figure 3.1.38 A scene of the development at the place of St.14 (31k 800m)

16) Place of St.15, St.16 (34k 700m, 36k 700m)

In the future, the Hanoi National University will be relocated to this area. As of now, it is dotted with private houses, and farmland spreads.

Source: JICA Study Team

Figure 3.1.39 A scene at the place of the St.15 (34k 700m)

Source: JICA Study Team

Figure 3.1.40 A scene at the place of the St.16 (36k 700m)

17) Place of St. 17 (38k 300m)

The St.17 is the terminal station of the Line 5 in this survey. In its vicinity, a vast extent of land, most of which is agricultural land, can be seen.

Source: JICA Study Team

Figure 3.1.41 A scene at the place of the St.17 (38k 300m)

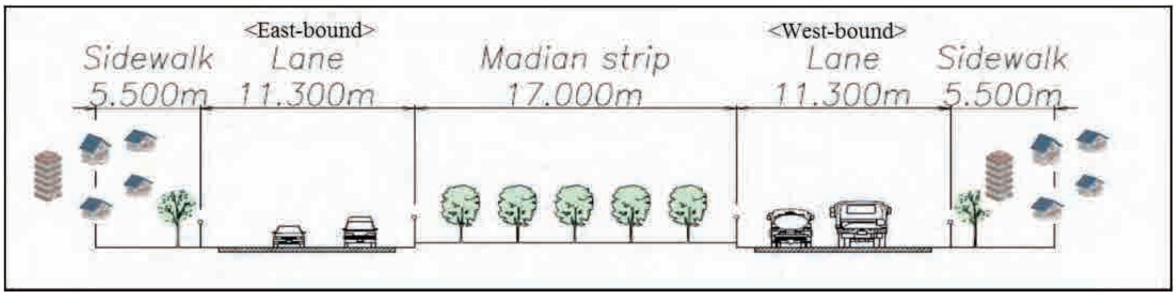
(2) A summary of the route plan

From the starting point to the ring road 3, railway structures will be constructed from the Van Cao Street to the Tran Duy Hung Street. As the existing road is ideally planned in terms of alignment and width, constructed lands are secured sufficiently from the viewpoint of railway construction. As it is intended to construct a railway line along the road in this plan, therefore, expropriation of lands is virtually hardly necessary in fact. This means that the plan is highly viable from the viewpoint of actual implementation. In addition, the plan will be performed in close conjunction with the construction work of railway infrastructures in the midtown area to establish an ideal urban traffic system.

As Thang Long road is constructed between the ring road 3 and the national conference hall on the terminal side, with the lands for railway construction reserved on the median strips, this space will be utilized and appropriated in principle from the viewpoint of reducing construction cost.

1) 5 km point from origin (urban area)

From the starting point to the 5 km point, the road sides are swarming with buildings as shown in Fig 3.1.42. Therefore, the railway line shall be confined within the road. In case an elevated structure is adopted, the viaduct shall be on the median strip. If the line runs underground, it shall be within the width of the road.

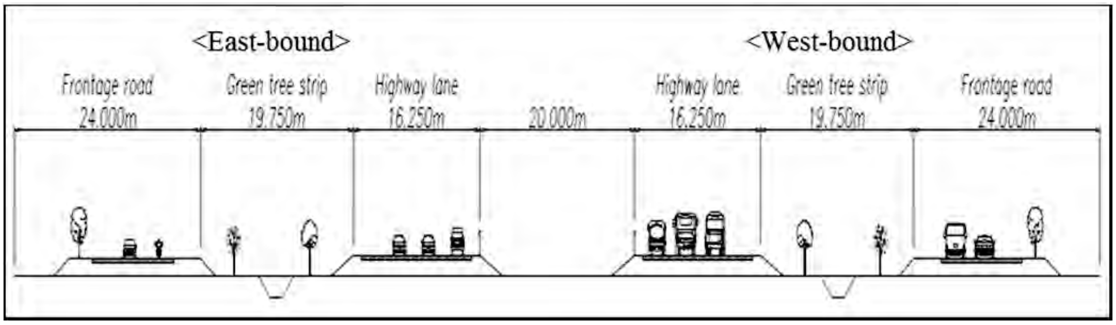


Source: JICA Study Team

Figure 3.1.42 5 km point from the starting point

2) 5 km to 33 km points (suburban area)

From the 5 km point up to the 33 km point, the planned railway line will be laid within the median strip of Thang Long road, which is composed of four frontage passes/groups of lanes: east-frontage pass, east-line, west-line and west-frontage pass, having comparatively broad separation strips against the adjacent frontage pass/lanes. See Fig 3.1.43. The plan to construct railway line within the median strip has been adopted in order to avoid any inconvenience caused by the structures at the intersection with VNR or interchanging points, even though each line has a relatively wide separation strip.



Source: JICA Study Team

Figure 3.1.43 A sectional view of Thang Long road

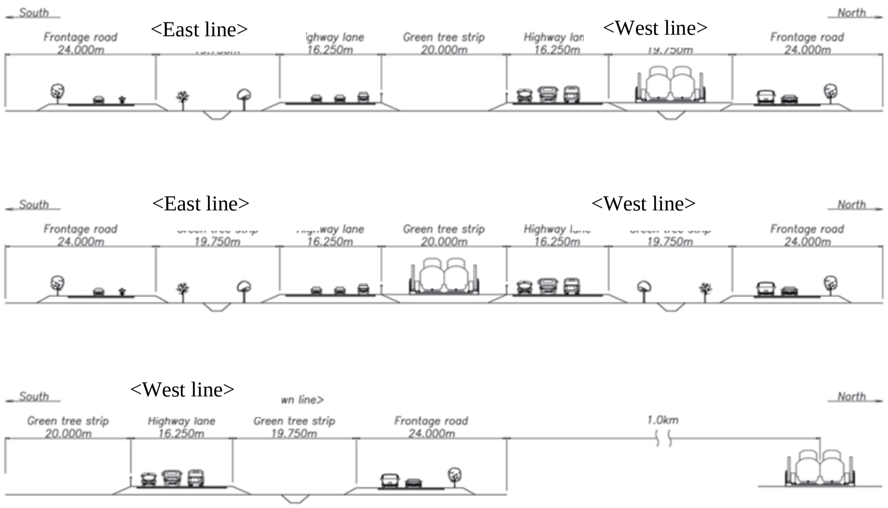
< Study on the position to construct the railway lines in suburban area >

The position for the construction of the railway lines on Thang Long road is examined here by comparing several drafts. Regarding the candidate locations, as well as the median strip between the main lanes, as mentioned in the Hanoi Master Plan, there is a similar separation strip between the main lane and the frontage pass. In addition, the place where the distance between the road infrastructure and railroad infrastructure is far (approximately 1 km north side of Thang Long road) is taken into consideration. In total, three drafts are examined.

As a result of the examination, if the railway is constructed in the location separated from Thang Long road, resettlement shall occur a lot mainly in exiting towns and a large amount of resettlement cost and land acquisition cost shall be required as shown in Table 3.1.2. In addition, in case the railway is constructed on the ground, on the one hand, there would be a problem of city development since the area is divided into parts. On the other hand, if the construction structure is elevated in order to solve the problem of community severance, the construction cost increases because construction of long sections would be required. Considering these difficulties, if the railway is constructed on the median strip of Thang Long road, the construction cost will be very low because the overhead crossings have already been constructed to solve the splitting of communities, and the railway can be constructed mainly on the ground.

In addition, as shown in Table 3.1.2, based on local investigation of the area near Thang Long road, the existing town area does not necessarily spread out only in either the north or south of Thang Long road. The town area spreads out both north and south. Moreover, future development project is planned in the area of both. Therefore, it is desirable to keep equal distance from Thang Long road to railway stations. Furthermore, since the interval between the main line and a frontage pass is very narrow in the intersection with VNR railroad as shown in Table 3.1.3, there is no space to construct the track. In an interchange section, a bridge whose length is 100 m or more is required. In consideration of the above-mentioned, it is admitted that the median strip between eastbound and westbound is advantageous. This plan will be promoted accordingly.

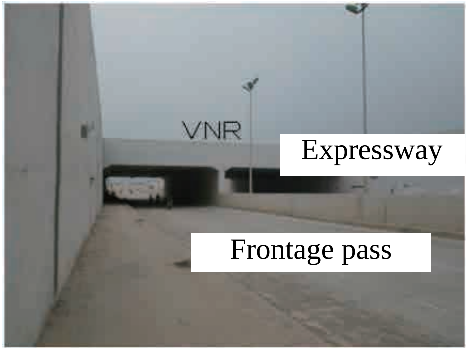
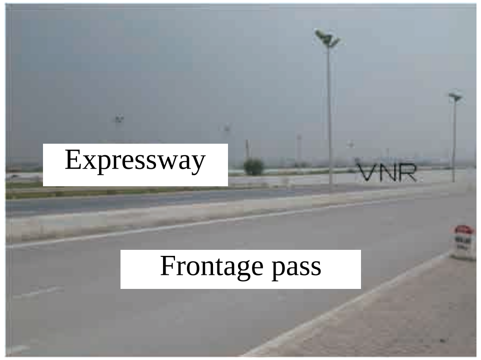
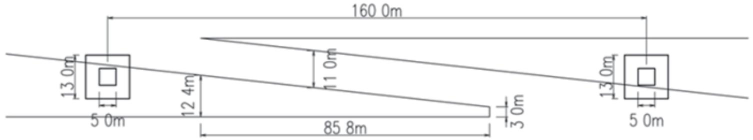
Table 3.1.2 A comparison of the track laying places in the section from 5 to 33 km points

	Draft (1)	Draft (2)	Draft (3)
Place of track	Frontage pass – main line	Median strip	North of the Thang Long road (approx. 1 km)
Sectional view	Draft (1) Draft (2) Draft (3) 		
Features	Convenient access to the areas north of Thang Long road Additional land acquisition is not required inside Thang Long road.	Access roads can be constructed on both sides of Thang Long road. Additional land acquisition is not required inside Thang Long road.	Formation of a new town will be planned by the station built approx., 1 km north of Thang Long road. Additional land acquisition is required outside Thang Long road.
Involved problems	Impossibility of track lying at the crossing point with the VNR line due to the zero clearance between the frontage pass and main lanes. A bridge with a span of 100 m or over is required at interchanging points. Viaducts are required at road junctions planned in the future.	None	Land acquisition is required along the entire route. Inhabitants shall be relocated.
Evaluation	△	○	×

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

Source: JICA Study Team

Table 3.1.3 A list of the problems involved in the draft (1)

	Crossing point with VNR	Interchanging point
Sectional view	 	  Estimated measurement-based bridge length
Features	The expressway and a frontage pass are close to the U-shaped retaining wall box at the crossing point with VNR (for about 1 km).	The entrance (exit) way crosses the track at the interchanging point to the expressway.
Involved problems	As there are no spaces to construct tracks or pillars, the railway line shall escape outward by running over a bridge to cross the expressway or the frontage pass. This requires a considerably large bridge as the angle of swing is limited.	A bridge is required to cross the entrance (exit) way. As the angle of entrance is small, the bridge will become rather long.
Evaluation	Long bridges shall be avoided as far as possible.	Bridges at a length of 160 m or over shall be avoided as far as possible.

Source: JICA Study Team

3) 33 km to 38 km points

The railway line crosses a national road route 21 at a point about 33 km from the starting point. It is currently planned to use Thang Long road up to the national road route 21. Since on the west side of the national road, Thang Long road will be extended in the future based on the Master Plan, the area near the edge of railway plan of the phase 2 in this study was adopted with an alignment following Thang Long road.

However, according to the extension plan of Thang Long road, width of a median strip is only 3 m and small to construct double-track railway. Consequently, in order to construct both roads and railway economically and efficiently, it is expected to reconsider width of the median strip in the current extension plan or interchanging plan to allow construction of the railway on the north side of Thang Long road.

(3) Plan of depot

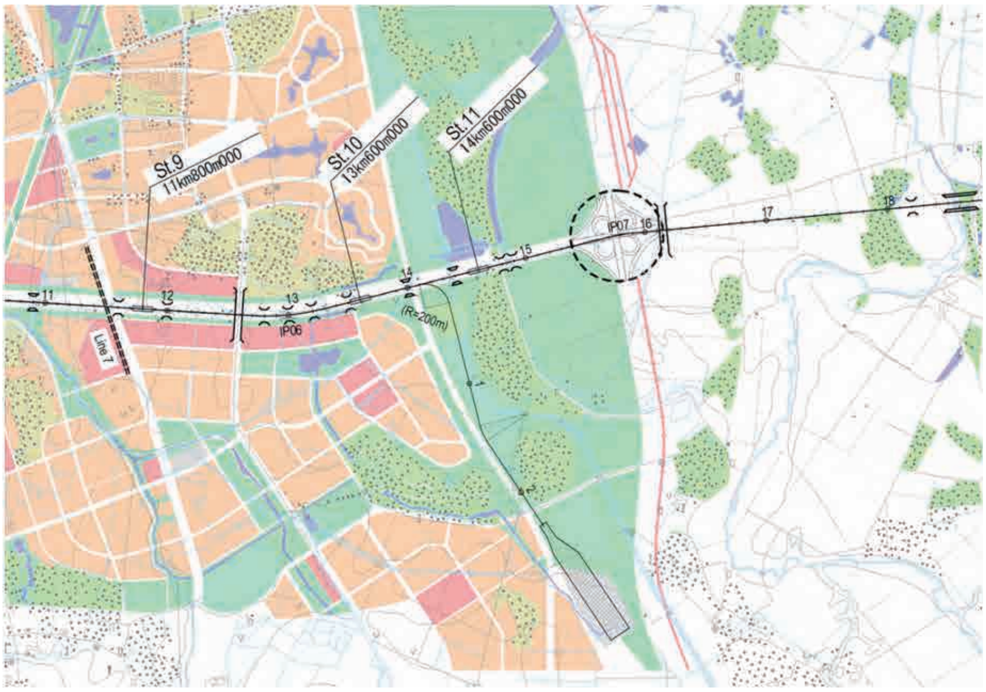
Depot is planned in consideration of the following points.

1) Smooth depot-in and depot-out operations
2) Installation of an operation center having a central role for train operation
3) Positioned as a total center for various maintenance services, the depot will be installed with maintenance/inspection offices for rolling stock, civil engineering, architectures and electric facilities.

Study Team assumes a space of about 17 ha for depot by considering the medium-term demands and proposes the sites chosen for the location of maintenance center, which will be near the St.10 (13k.600m) on the terminal side (see Fig 3.1.44). The sites have been selected to meet the following requirements:

(1) Preparation of depot is necessary in the phase 1.
(2) It is as close to the main line as possible.
(3) Noise and vibration hardly affect private houses.
(4) It is outside the area under a known development plan.
(5) It is adjacent to road and easy for operation staff to go to and leave work and to carry materials in depot.

In case the number of train-sets has increased in the future, another will be constructed. Study Team proposes the best location for depot after comparing several options (regarding other options, refer to 3.10 Technical terms and other considered matters):



Source: JICA Study Team

Figure 3.1.44 Place of the proposed maintenance center

3.1.3 Station distribution plan

Under the station distribution plan in the phase 1, stations are distributed to constitute a railway network in the Hanoi midtown while placing emphasis on the convenient interchange to/from other lines, based on the section of subway/urban railway networks in Hanoi City's "Master Plan for the Development until 2030, with a Vision to 2050." Study Team set the distance between stations at about 1 to 1.5 km in the midtown area on the assumption that a walking area is 400 to 600 m in distance or 5 to 10 minutes in walking while the distance between stations at 2 to 3 km in the suburbs on the assumption that a walking area is about 1,500 km in distance.

With regard to the 2nd phase, the quick deliverability to a terminal station was taken into consideration. Here it shall be noted that an established city area is formed and a development project is clear. Now stations are planned at the point which can expect demand. From the viewpoint, at first, in the station distribution plan in the Phase 2, Study Team had planned 3 stations along a section, about 24 km in length, in the existing urban districts of Quoc Oai and Hoa Lac and the terminal area, then had proposed to adopt beneficiary charge method for the construction of new stations corresponding to "Rise in land prices along Hanoi Line 5 and diversion of betterment gains into project," as mentioned in 4.3.1. As a result of discussions in Vietnam, however, Study Team planned 17 stations in total, 10 stations in Phase 1 and 7 in Phase 2, in order to establish consistency with the result of local study in Vietnam and to reflect opinions to promote planning in advance the construction of stations even in Phase 2. As the Route selection allows posting various stations in various districts in the future, it is possible to construct new stations according to the development in the suburbs of Hanoi in the future.

In addition, regarding the location of stations, there are slight differences between the proposal of this study and that of local study; therefore, reasons why this study proposes different locations are explained in Table 3.1.4.

Table 3.1.4 List of station locations

No	Station name (tentative)	Kilometerage	Distance (m)	Structure type (idea)
<Phase 1>				
St.1	Ho Tay	0K100M		Elevated (Underground)
St.2	Kim Ma	1K200M	1,100	Elevated (Underground)
St.3	Lang Trung	2K400M	1,200	Elevated (Underground)
St.4	Trung Kinh	3K900M	1,500	Elevated (Underground)
St.5	Trung Hoa	4K700M	800	Elevated (Underground)
St.6	Me Tri	6K400M	1,700	Ground level
St.7	Giao Quang	8K600M	2,200	Ground level
St.8	Tay Mo	10K500M	1,900	Elevated
St.9	An Tho	11K800M	1,300	Ground level
St.10	An Khanh	13K600M	1,800	Ground level
<Phase 2>				
St.11	Song Phuong	14K600M	1,000	Ground level
St.12	Quoc Oai	20K500M	5,900	Ground level
St.13	West Quac Oai	23K700M	3,200	Ground level
St.14	Hoa Lac	31K800M	8,100	Ground level
St.15	Tien Xuan	34K700M	2,900	Ground level
St.16	Trai Moi	36K700M	2,000	Ground level
St.17	Ba Vi	38K300M	1,600	Ground level

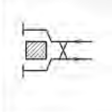
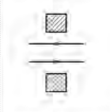
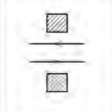
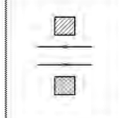
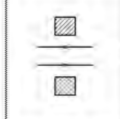
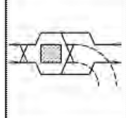
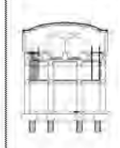
Source: JICA Study Team

Table 3.1.5 Comparison between proposals of this study and Vietnamese study

No.	Station name (tentative)	Kilometerage (this study)	Kilometerage (Vietnamese study)	Reason of promoting proposal of JICA Study Team
< Phase 1 >				
St.1	Ho Tay	0K100M	0K105M	Similar
St.2	Kim Ma	1K200M	1K150M	Similar
St.3	Lang Trung	2K400M	2K380M	Similar
St.4	Trung Kinh	3K900M	3K880M	Similar
St.5	Trung Hoa	4K700M	4K680M	Similar
St.6	Me Tri	6K400M	6K440M	Similar
St.7	Giao Quang	8K600M	8K600M	Similar
St.8	Tay Mo	10K500M	10K280M	St.8 shall be elevated to cross over current VNR line. The station is located right above Line.6
St.9	An Tho	11K800M	11K800M	Similar
St.10	An Khanh	13K600M	13K100M	In order to secure straight alignment for installing scissors crossing as this section is ending point of Phase 1.
< Phase 2 >				
St.11	Song Phuong	14K600M	14K630M	Similar (It is necessary to have consistency with the future development plan.)
St.12	Quoc Oai	20K500M	20K550M	Similar (It is necessary to have consistency with the future development plan.)
St.13	West Quoc Oai	23K700M	23K750M	Similar (It is necessary to have consistency with the future development plan.)
St.14	Hoa Lac	31K800M	31K800M	Similar (It is necessary to have consistency with the future development plan.)
St.15	Tien Xuan	34K700M	34K750M	Similar (It is necessary to have consistency with the future development plan.)
St.16	Trai Moi	36K700M	36K650M	Similar (It is necessary to have consistency with the future development plan.)
St.17	Ba Vi	38K300M	39K250M	In order to leave flexibility for selection of extended destination as the alignment near 39K becomes curve.

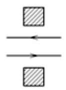
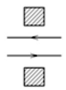
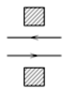
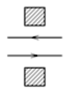
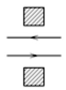
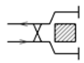
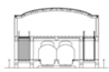
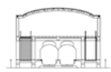
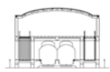
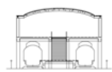
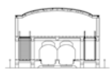
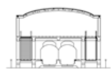
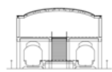
Source: JICA Study Team

Table 3.1.6 Specification of stations (St.1-St.10, elevated)

	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10
Alignment										
Section view of station										
Kilometerage in the center of station	0km100m	1km200m	2km400m	3km900m	4km700m	6km400m	8km600m	10km500m	11km800m	13km600m
Type of station	Elevated	Elevated	Elevated	Elevated	Elevated	Ground level	Ground level	Elevated	Ground level	Ground level
Type of platform	Island	Island	Island	Island	Island	Opposite platforms	Opposite platforms	Opposite platforms	Opposite platforms	Island
Length of platform	170m	170m	170m	170m	170m	170m	170m	170m	170m	170m
Width of platform	8.0m	8.0m	8.0m	8.0m	8.0m	2x5.3m	2x5.3m	2x5.3m	2x5.3m	8.0m
No. of gate	1	1	1	1	1	1	1	1	1	1
No. of Elevator (inside gates)	1	1	1	1	1	2	2	2	2	1
No. of Escalator	3	3	3	3	3	2	2	2	2	2
No. of toilet	for men 1, for women 1, mulitifunctional 1									
Transfer to/from other	Line2	Line3		(Line4)	(Line8)			(Line6)	(Line7)	

Source: JICA Study Team

Table 3.1.7 Specification of stations (St.11-St.17)

	St.11	St.12	St.13	St.14	St.15	St.16	St.17
Alignment							
Section view of station							
Kilometerage in the center of station	14km600m	20km500m	23km700m	31km800m	34km700m	36km700m	38km300m
Type of station	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
Type of platform	Opposite platforms	Opposite platforms	Opposite platforms	Island	Opposite platforms	Opposite platforms	Island
Length of platform	170m	170m	170m	170m	170m	170m	170m
Width of platform	2x5.3m	2x5.3m	2x5.3m	8.0m	2x5.3m	2x5.3m	8.0m
No. of gate	1	1	1	1	1	1	1
No. of Elevator (inside gates)	2	2	2	1	2	2	1
No. of Escalator	2	2	2	2	2	2	2
No. of toilet	for men 1, for women 1, multifunctional 1						
Transfer to/from other							

Source: JICA Study Team

1) Ho Tay (St.1)

This is the starting point located on the south of the Hoang Hoa Tham Street, south of the Ho Tay (West Lake), having a role as an interchange station to/from the Line 2. The station shall cope with the traffic demand to/from various bustling facilities including the national stadium and surrounding residential areas. In the station layout plan, Study Team proposes plan to ensure the convenience of transfer between the Line 5 and the Line 2 from the viewpoint of users.

2) Kim Ma (St.2)

The station is located on the north of the Kim Ma Street and surrounded by large-size hotels and crowded facilities. Construction of buildings for commercial purposes such as Lotte Center Hanoi is under way in this area. The Line 3 is planned along this Kim Ma Street burdened with a heavy traffic volume. Therefore, the Kim Ma station shall have a role as an interchange node to/from the Line 3. In the station layout plan, Study Team proposes plan to ensure the convenience of transfer between the Line 5 and the Line 3 from the viewpoint of users.

3) Lang Trung (St.3)

This station is located on the terminal side at the crossing between the Chua Lang and Nguyen Chi Thanh Streets. There are universities and condominiums around the station to suggest the existence of a fairly large volume of traffic demand of pedestrians within the walking distance.

4) Trung Kinh (St.4)

This station is located on the starting point side at a crossing where the expansion of road width is planned. Near the station, there are a number of universities, high-rise buildings and condominiums even at present. In case the Line 4 is constructed in the future, therefore, the station will have the role of an exchanging node. Study Team placed emphasis on the station layout to constitute an urban railway network expected in the master plan on the urban area side of the ring road 3 including the Trung Hoa station.

5) Trung Hoa (St.5)

Located on the starting point side at the intersection with the ring road 3, the station is surrounded by Big C and other large-scale commercial facilities, a national conference hall, high-rise buildings and condominiums with potential traffic demand. As this trend is further progressing as a compound urban development area, the station is required to cope with the demand of its influential areas. In this area, it is desirable to construct comfortable pedestrian spaces by connecting the station with the surrounding facilities with decks and terraces. As the plan of the Line 8 is scheduled in the master plan, the station layout shall be drawn by assuming that a role of interchanging station will emerge in the future.

6) Me Tri (St.6)

Among the stations located on the west of the ring road 3 (within Thang Long road), this station is the closest to the midtown. It shall cope with the demand of the existing city areas. Study Team will design the station by keeping an eye on the suburban residence area development plan in the future. Siding tracks will also be constructed to ensure the security of train operation and prepare for unexpected situations (vehicle breakdown, etc.). An over-track station building will be constructed to facilitate smooth approach from the surrounding roads.

7) Giao Quang (St.7)

Demand for the urban areas near this station is expected. The station will be planned while taking into consideration the suburban residential area development plan in the future.

8) Tay Mo (St.8)

This is a crossing point with VNR freight line. As there is a plan to rehabilitate the VNR line as Urban Railway Line 6 with double-track and electrification, the station is positioned as an interchanging station to/for the Line 6 in the future. However, since construction schedule of the line has not been settled yet, it is necessary to promote construction of this station considering the progress of the Line 6.

9) An Tho (St.9)

A large-scale residential area development plan is now underway in the vicinity of the station. It is important to make the station linked with the station plaza to take into account the approach for pedestrians, motorbike users and bus passengers. Since a crossing with Line 7 is planned on the starting point side, the station layout and alignment shall be designed to enable transfer to the line.

10) An Khanh (St.10)

This station shall be designed as the terminal in the phase 1 and be linked with the facilities of car inspection shed. As there are urban areas in the vicinity of the station, increase in demand is expected.

11) Song Phuong (St.11)

This station is located on the east of the ring road 4. In this vicinity, there have been some urban areas already. Moreover, as large-scale projects including the construction of the ring road 4 are planned in the future, the possibility to construct this station in Phase 1 depending on their progresses needs to be considered.

12) Quoc Oai (St.12)

This station is planned to be located on the east side of Quoc Oai district where some urban areas can be seen in the phase 2. As an existing urbanized district together with the projected Quoc Oai eco-town plan in the future suggests the existence of sizable potential traffic demand. As an important railway station in the eco-town plan, it will have a station plaza in front attached with large motorbike parking lots and other facilities to promote public traffic measures.

13) West Quoc Oai (St.13)

This station is located on the west side of Quoc Oai district where some urban areas are already existed and on the point about 3 km far from St.13. Role of this station is same as that of St.12, but it is necessary to promote its construction together with the progress of eco town planning.

14) Hoa Lac (St.14)

This is a terminal station in the phase 2. The concept of Hoa Lac High-Tech Park is already taking shape to gather about 230,000 people in 2020 according to the master plan. The Hanoi National University is expected to come to an adjacent site. Railway users will increase when access from the midtown of the Hanoi city is facilitated after the construction of the station. In the plan of Hoa Lac High-Tech Park, a space for the station plaza is prepared at the site of the station. Utilization of railway line will be accelerated by the construction of motorbike parking lots and through the cooperation with the buses operated to connect the station with the High-Tech Park and the facilities in the surrounding areas.

15) Tien Xuan (St.15)

This station is located on the area which Hanoi National University will be relocated to. Since most of the railway users are supposed to be students, station construction together with the construction plan of university is indispensable.

16) Trai Moi (St.16)

This station is located on the west of Hoa Lac district. In the same way as St.15, it is essential to construction the station in accordance with town planning including construction plan of university.

17) Ba Vi (St.17)

This is a terminal station in the phase 2. At present, vast extent of land, mostly agricultural land, can be seen in the vicinity of the station. On the west side of the station, a Vietnamese national culture/sightseeing village is now under construction, while a number of resort facilities are also following suit in the suburbs of the Hanoi city. Ba Vi which is an upmarket resort place can be accessed by bus. In case the style of pastime by Vietnamese people has changed in the future, those living in the center of the Hanoi city will certainly take trains to spend their leisure time in the suburbs.

3.1.4 Discussions on the structure (elevated, ground level and underground)

Study Team discussed the structure (elevated, ground level and underground) of stations from the following viewpoints:

1) Feasibility of design as a railway structure
2) Landscape
3) Convenience for users
4) Relation with existing structures
5) Correspondence to the development in the surrounding areas
6) Economy in the construction cost

Study Team first assumed several alternatives of the railway of the elevated, ground level and underground types along the entire route. However, in this study, Study Team only mentioned on the plans of elevated and underground types in midtown (regarding other options, refer to 3.10 Technical terms and other considered matters) and clarified the merits and demerits of each alterative to make the basic material for the surveys at the later stages. Details of each type are defined as follows:

Elevated type:

Tracks are laid at elevated places, 7 to 8 m or higher from the ground surface, using girders, bridge piers and rigid-frame viaducts, including girders to cross rivers and roads in case the sections before and after the rivers and roads are of the elevated type.

Ground level type:

Tracks are laid at lower places, up to 7 or 8 m above the ground surface, using embankments, including girders to cross rivers/roads in case the sections before/after the rivers/roads are of the ground level type.

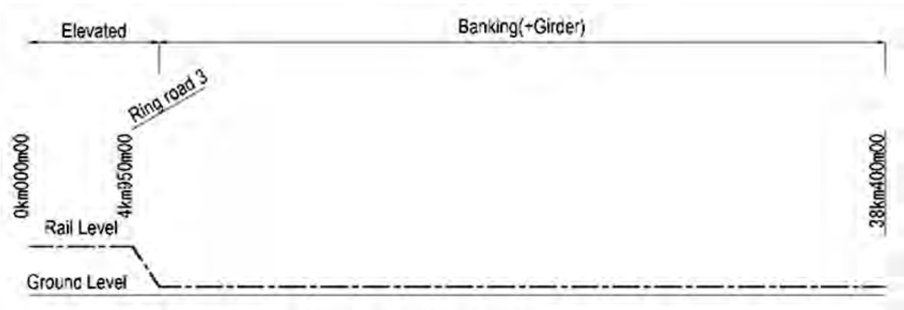
Underground type:

Tracks are laid underground using shield and cut and cover tunnels.

(1) Idea of the elevated- ground level type

This is an idea to adopt a structure of the elevated type from the starting point to the ring road 3 (4K950M point) to confine railway structures within the median strip, primarily for the purpose of avoiding the ground level road-crossings scattered here and there. Beyond that point, the railway will be constructed to have the most economical structure of the ground level type, with the tracks placed within the median strip.

As for the overbridge crossing Thang Long road, track is planned to be constructed under its girders.So far, Study Team has confirmed that there are 10 flyovers to cross Thang Long road, where the tracks will be laid beneath the girders.



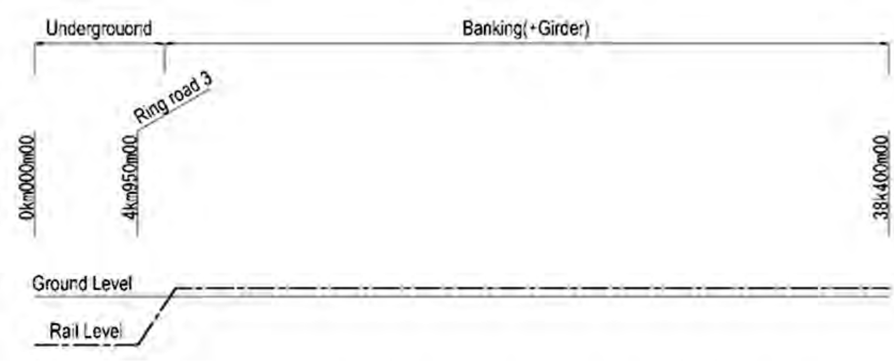
Source: JICA Study Team

Figure 3.1.45 Idea of the elevated-ground level type

(2) Idea of underground-ground level type

This is an idea to adopt a structure of the underground type from the starting point to the ring road 3 (4K950M point) to confine railway structures within the median strip, primarily for the purpose of avoiding the ground level road-crossings scattered here and there. Beyond the national conference hall (5K860M point) or Thang Long road, the railway will adopt the most economical ground level type as the tracks are within the median strip of the road.

As for the overbridge crossing Thang Long road, track is planned to be constructed under its girders.So far, Study Team has confirmed that there are 10 flyovers to cross Thang Long road, where the tracks will be laid beneath the girders.



Source: JICA Study Team

Figure 3.1.46 Idea of the underground-ground level type

The main investigation designed railway lines so that the lines would be in agreement with the Master Plan of Hanoi city that the Vietnamese government already approved. However, some of the designs do not agree with the Master Plan as a result of technical examinations. The greatest point of discussion among the disagreement is the railway structures in urban areas. The concept raised in this investigation is described below.

1) Perspective on the connection with facilities around stations

Concerning the connection between stations and surrounding facilities, the freedom of designs for connections between stations and surrounding facilities becomes higher when stations are elevated structures. (Commercial facilities and stations can be constructed as joint development.) Conversely, in case of underground structure, stations and those facilities are connected through underground passages, but there might be some technical problems in construction depending on structure of the facilities and physical relationship between stations and surrounding facilities. (In terms of accessibility, however, there is no huge difference between elevated and underground structures.)

2) Perspective of preventing damages by flood and leakage of water

The city of Hanoi suffers damage by flood caused by heavy rains every year. Thus, the adoption of underground structures requires adequate measures for inundation not only in hardware but in software aspects. Since the installation of elevated structures does not require special measures for flooding, it is advantageous to adopt them as much as possible. In addition, locating in the delta of the Red River, the groundwater level of the city of Hanoi is high. Thus, sufficient prevention of water leaks through water-resistant structures and drainage system by pumping facility is essential. Since the installation of elevated structures does not require special measures for water leakage, it is advantageous to adopt them as much as possible.

3) Perspective of urban landscape and convenience of transit

The disadvantages of elevated railway structures compared to underground structures are urban landscape and convenience of transit. It is known that underground structures are advantageous in terms of the urban landscape. However, in terms of elevated structures, designs that blend in with the surrounding landscape can be adopted. Concerning the convenience of transit with other lines, the use of stairs and escalators cannot be avoided in underground structures due to the three-dimensional crossing of railways. Thus, there is no major difference between elevated and underground structures considering that the details of the structures will be designed with consideration for the movement of users.

Based on the above observations, this investigation recommends the plan for elevated structures with the main focus on the freedom of designs in the connection between stations and surrounding facilities and the risk of flooding and water leakage based on an understanding of the advantages and disadvantages of elevated and underground structures. (The recommendation for elevated structures is not necessarily based on the cost of projects alone.) Meanwhile, the plan for elevated structures is relatively disadvantageous to underground structures in terms of urban landscapes and convenience of transit. The Vietnamese government will make the final decision after a comprehensive review of the advantages and disadvantages of both plans.

Therefore, this study indicates both plans of elevated and underground in terms of structures in urban area.

Table 3.1.8 Comparison between different ideas

Item of comparison	Idea 1	Idea 2	Remarks
from Starting point to ring road 3	Elevated	Under-ground	
from ring road 3 to Terminal point	Ground level	Ground level	
1. Alignment			
Horizontal alignment	◎	◎	Not a huge problem even near the ring road 2
Vertical alignment	◎	◎	
2. Station distribution plan (Network)	◎	◎	For the both plans, connecting stations with other lines can be constructed.
3. Linkage with surrounding areas			
Communication with surrounding facilities	◎	△	When passageway for communication with surrounding facilities of station is constructed, construction work in underground can be large scale.
Interchange with other railway lines	○	◎	Construction work of the passageway in underground becomes large-scale. The distance of perpendicular direction which users walk can be reduced.
Connection with motorbikes and buses	○	△	In the case of an elevated structure, the space under elevated structure can be used effectively such as motorbike parking lots. As a result, it becomes easy to implement measures for railroad use promotion.
4. Landscape	△	◎	Even if an elevated structure, it is necessary that the structure with excellent design is designed.
5. Construction work			
Road occupancy and lands for work	○	○	
Construction cost	◎	△	In the case of an elevated structure, it is easy to secure the space for parking lots, convenient facilities or commercial facilities. In case of the underground, initial investment increases as ventilation and drainage pump, elevators & escalators facilities, and fire-fighting facilities become large scale. Also, temporary works, anti-disaster facility and air conditioner become large scale. Compared with an elevated structure, construction cost of underground structure increases 1,300 million USD.

	Geological condition	△	△	Soft subsoil, but possible to deal with.
	Construction period	○	△	Construction period of underground works is a little longer than that of elevated works.
6. Maintenance				
	Inundation	◎	△	Measures to prevent inundation from gateway or ventilator are required. In preparation for inundation, maintenance of measures manual and training is also required.
	Environment (Noises)	○	◎	For the elevated structure, possible to deal with by installing soundproof wall.
	(Vibration)	○	○	
	(Sunlight)	○	◎	The elevated structure leads to shading, but there won't be a problem as road width is large.
	Maintenance cost	○	△	As for underground structure, running cost increases as equipment like ventilation or drain pump and leakage control construction are required. Maintenance of underground section is performed as nighttime work.
Overall evaluation		◎	○	

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

Source: JICA Study Team

3.2 Rolling Stock Equipment

3.2.1 Basic concept

Line 5 has the characteristics of both of an urban railway, which basically has short station spacing and stops at every station, and a suburban railway, which has long station spacing and connects stations at high speed. In the future, however, the plan is to schedule the construction of many new residential areas along the Line 5. When the residents of these areas commute to the office or school in the city of Hanoi or Hoa Lac High-Tech Park using the Line 5, it is expected that the trains will be overcrowded during rush hour in the morning and evening. Therefore, rolling stock for the line shall be suitable for stable transportation during peak times.

Source: JICA Study Team

Figure 3.2.1 Image of appearance of rolling stock

Source: JICA Study Team

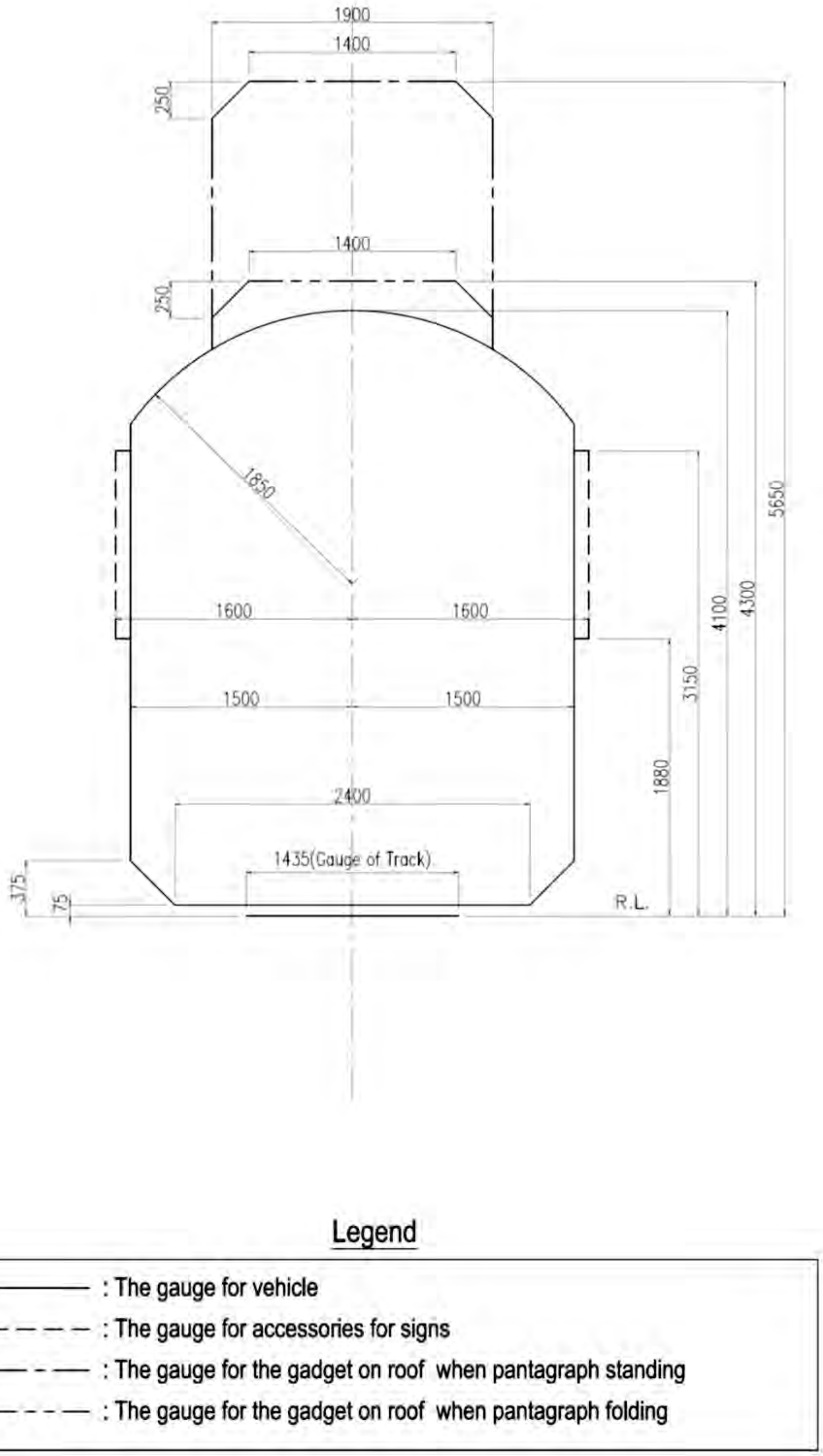
Figure 3.2.2Image of train’s interior

3.2.2 Technical dimensions

The technical dimensions shall be based on the urban railway standard dimensions, STRASYA (STandard urban RAilway SYstem for Asia), which was summarized mainly by the JARTS based on the excellent Japanese railway system.

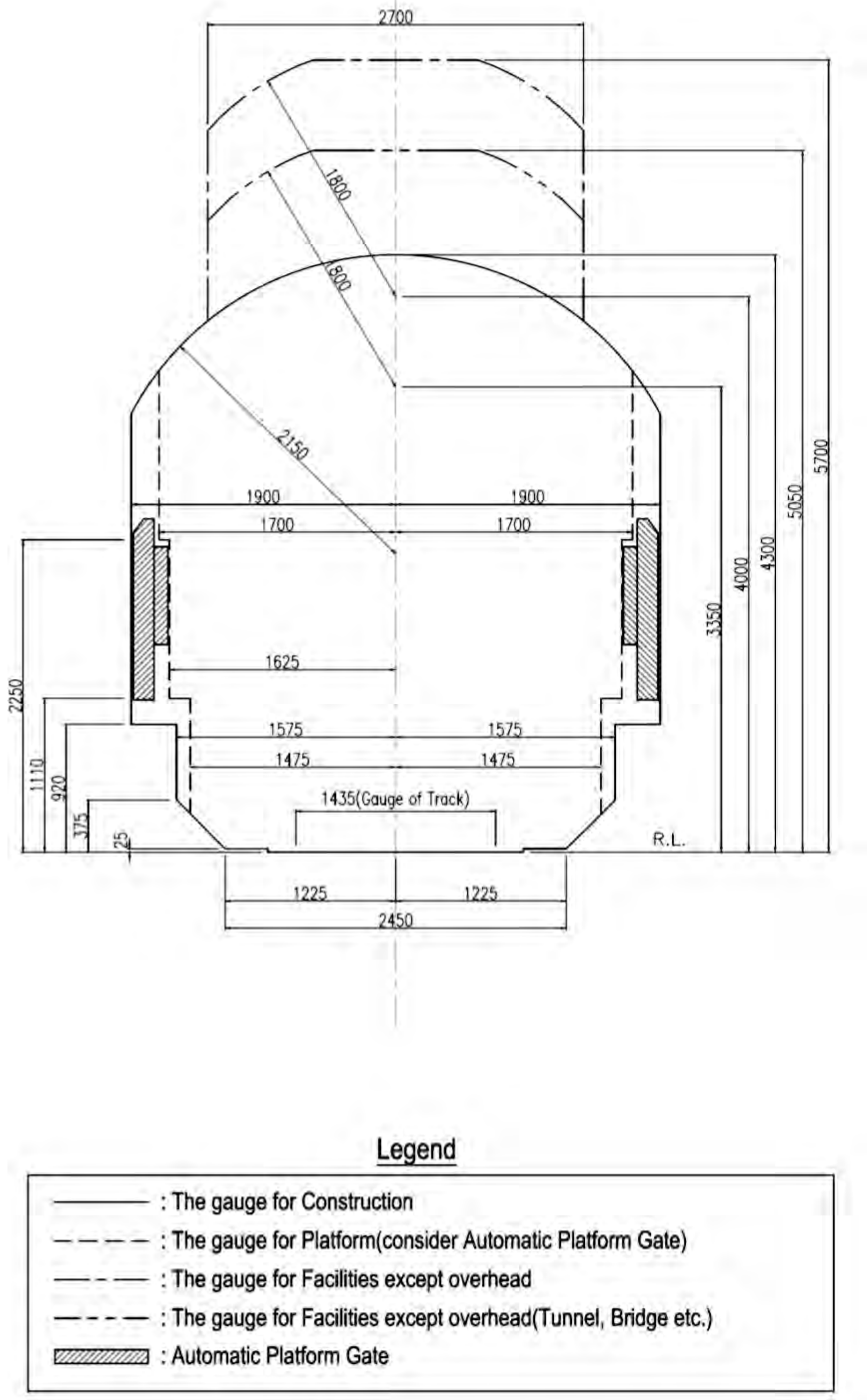
(1) Rolling stock gauge and clearance gauge

The rolling stock gauge and clearance gauge shall be compliant with STRASYA. The rolling stock gauge diagram and clearance gauge diagram are shown in Fig 3.2.3 and Fig 3.2.4, respectively.



Source: JICA Study Team

Figure 3.2.3 Rolling stock gauge diagram

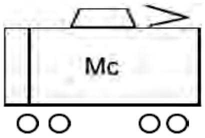
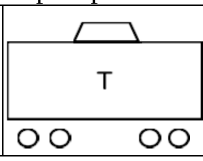
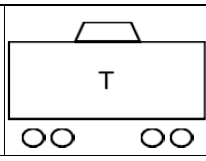
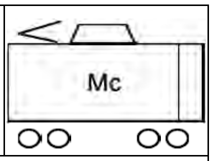


Source: JICA Study Team

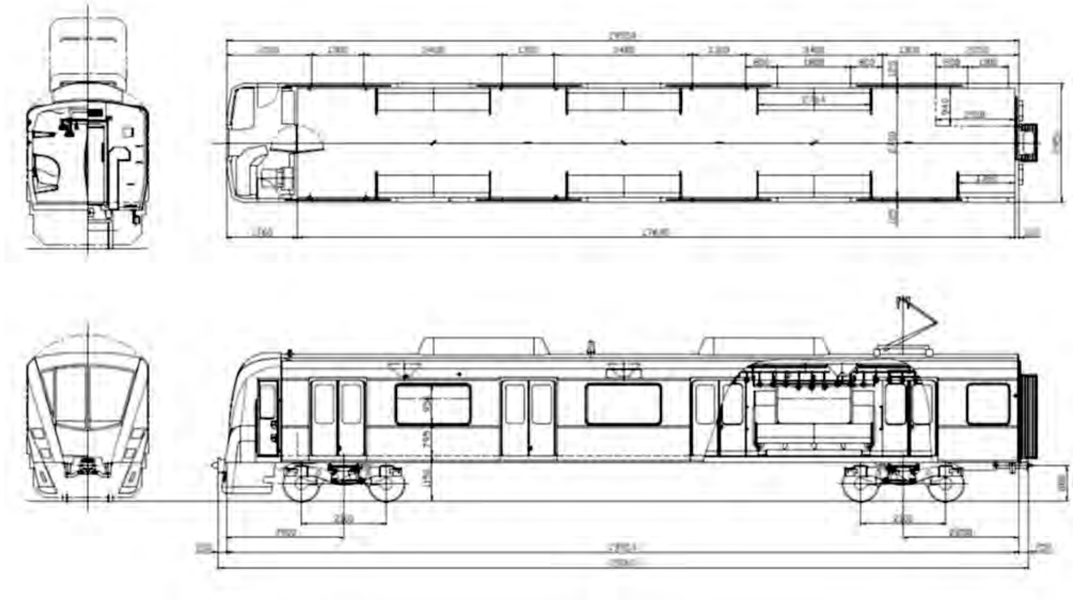
Figure 3.2.4 Clearance gauge diagram

(2) Principal specifications table and car type diagram

Table 3.2.1 Principal specifications table

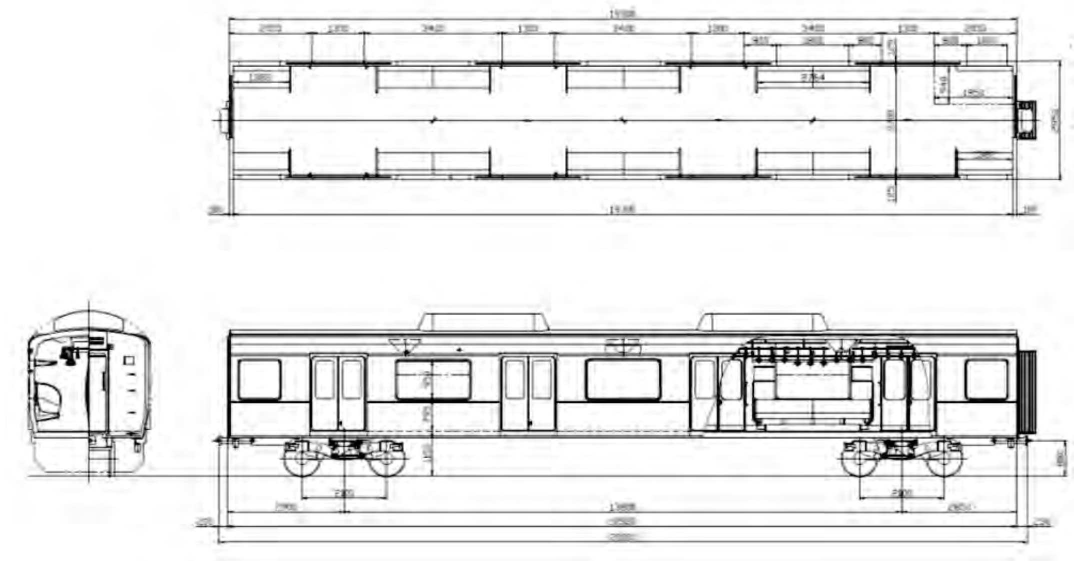
Item				
Gauge	1435 mm			
Car type	Mc	T	T	Mc
Mass (Empty)	37 t	29 t	29 t	37 t
Power source	Overhead line: DC 1500 V			
Maximum design speed	130 km/h			
Acceleration	3.3 km/h/s (0.92 m/s^2)			
Deceleration	Service brake: 3.6 km/h/s (1.0 m/s^2), Emergency brake: 4.5 km/h/s (1.25 m/s^2)			
Overall length of car body	20,000 mm	20,000 mm	20,000 mm	20,000 mm
Overall width of car body	2,950 mm	2,950 mm	2,950 mm	2,950 mm
Car body height	4,110 mm (At the time of descent of pantograph)	4,090 mm	4,090 mm	4,110 mm (At the time of descent of pantograph)
Floor height	1,150 mm	1,150 mm	1,150 mm	1,150 mm
Passenger capacity (Seating capacity)	169 (39)	183 (45)	183 (45)	169 (39)
Bogie	Bolster Bogie	Bolster Bogie	Bolster Bogie	Bolster Bogie
Distance between two bogies	13,800 mm	13,800 mm	13,800 mm	13,800 mm
Wheelbase	2,100 mm	2,100 mm	2,100 mm	2,100 mm
Gear ratio	7.17	------------	------------	7.17
Traction motor	Induction motor, 190 kW × 4			
Control device	VVVF IGBT inverter, 1C-2M			
Auxiliary power supply system	------------	Storage battery	APS/LVPS	------------
Pantograph	Single-arm type	------------	------------	Single-arm type
Motor-driven air compressor	------------	CP	------------	------------
Brake system	All electric command brake equipment (Service brake, emergency brake, parking brake, security brake, wheel slide protection device)			
Train protection system	ATO			

Source: JICA Study Team



Source: JICA Study Team

Figure 3.2.5 Type of rolling stock (Mc)



Source: JICA Study Team

Figure 3.2.6 Type of rolling stock (T)

(3) Speed and acceleration/deceleration of rolling stock

The maximum running speed was investigated and considered between 120 km/h and 160 km/h and various conditions, such as train performance curves derived from acceleration performance and maximum speed, cost for equipment, and other factors, were taken into account. Then, the maximum design speed shall be 130 km/h and the maximum running speed shall be 120 km/h. Acceleration and deceleration are as shown below.

Maximum design speed: 130 km/h
Maximum running speed: 120 km/h
Acceleration: 3.3 km/h/s (0.92 m/s^2)
Deceleration: Service brake 3.6 km/h/s (1.00 m/s^2)
Emergency brake 4.5 km/h/s (1.25 m/s^2)

(4) Train set

One train set shall be composed from four trains, when the line starts its operation, according to the demand forecast and the train schedule based on the forecast. After that time, the number of trains shall be increased to six and also eight according to the growth in demand.

Opening: Mc - T - T - Mc
Six-car-trains: Mc - T - **M - T** + T - Mc (Additional cars are in bold)
Eight-car-trains: Mc - T - M - T - **M - T** - T - Mc (Additional cars are in bold)
Tc: control trailer, M: motor car, T: trailer, -: coupling,

Note that the possibility to couple the train sets for operation shall not be considered for the car structure. There is the following idea. There is a concept in which two four-car train sets are coupled to form eight-car train sets and operate them as two four-car train sets according to the demand during daytime hours or in inactive zones. Although this concept will be advantageous in terms of electric cost reduction, it will be finally disadvantageous when considering the cost for manufacturing cars, the costs of coupling/decoupling operations and maintenance work, and the risk of failure.

(5) Passenger capacity and mass of car

The passenger capacity is defined as follows and the capacities of each car are shown in Table 3.2.2.

Passenger capacity (person) = Seating capacity (person) + Standing capacity (person)
Standing capacity (person) = Floor area for the standing passengers (m^2) x 4 (person/m^2)
Floor area for the standing passengers: Car floor area except both area of seat and area within 250 mm from the front edge of seat

Table 3.2.2 Passenger capacity of each car (Unit: person)

	Leading car	Middle car
Seating capacity	39	45
Standing capacity	122	138
Passenger capacity	161	183

Source: JICA Study Team

Additionally, based on the numbers above, the transportation capabilities per car for the passenger capacity and full capacity (with passengers of standing capacity x 1.5) of each formation are shown in Table 3.2.3.

Table 3.2.3 Passenger capacity of each train sets (Unit: person)

	Four-car train sets	Six-car train sets	Eight-car train sets
Seating capacity	168	258	348
Standing capacity	520	796	1,072
Passenger capacity	688	1,054	1,420
Transport capacity in case of full train	948	1,452	1,956

Source: JICA Study Team

For the mass of each car type, the types of mass are defined as follows and shown in Table 3.2.4. To calculate the masses, the mass per passenger is assumed as 55 kg.

AW0: Mass of empty car

AW1: Mass of car with passenger capacity. The number of passengers per unit about floor area for the standing passengers (1 m^2) is four.
AW1 = Empty car + (Seating capacity + Standing capacity) x 0.055 (t)

AW2: Mass of car with full passenger capacity. This value is used for various calculations for normal operation. The number of passengers per unit about floor area for the standing passengers (1 m^2) is six.
AW2 = Empty car + (Seating capacity + Standing capacity x 1.5) x 0.055 (t)

AW3: Maximum mass of car with passengers. This value is used for calculations of axle load and various strengths. The number of passengers per unit about floor area for the standing passenger (1 m^2) is eight.
AW3 = Empty car + (Seating capacity + Standing capacity x 2.5) x 0.055 (t)

Table 3.2.4 Mass of car type (Unit: t)

	Mc	T
AW0	37.0	29.0
AW1	45.9	39.1
AW2	49.2	42.9
AW3	56.0	50.5
Max. axle load	14.0	12.6

Source: JICA Study Team

(6) Car body

1) Material of car body

The major materials for rolling stock are steel, stainless steel, and aluminum alloy. They have their characteristics and are shown in Table 3.2.5.

Table 3.2.5 Comparison of major materials for car body

Characteristic \ Material	Steel	Stainless steel	Aluminum alloy
Strength	○	◎	△
Workability	◎	△	△
Corrosion resistance	×	◎	○
Fire resistance	◎	◎	△
Cost	○	○	△
Mass	×	○	◎
Overall rating	**△**	**◎**	**○**

Source: JICA Study Team

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

The railway cars of recent years are commonly made of lightweight stainless steel or aluminum alloy to reduce power consumption during operation. These materials also have the characteristics of high corrosion resistance and thus do not require coating. This enables minimization of life-cycle cost and reduction of the environmental load. In consideration of the fact that, in particular, Vietnam has a long, hot humid season, stainless steel shall be adopted due to its superior corrosion resistance and flawless characteristics in other aspects.

2) Door structure

For the purpose of ensuring punctuality through the reduction of station stop time and smooth boarding and exiting of the cars, the number of doors on one side shall be four (i.e. eight doors per car). They are double sliding doors with a door width of 1,300 mm. This specification complies with the standard of other lines of the Hanoi urban railway, such as Line 2, and takes into account the possibility of direct operation in the future. Additionally, all the seats shall be long seats in consideration of the congestion rate in the future.

All emergency exits shall be located at the front of the leading car on the assumption that the railway cars of Line 5 run on underground lines, but it shall not have a penetration structure because the formations will not be coupled.

3) Equipment of passenger compartment

The seating configuration shall be long seats suitable for mass transportation and shall enable smooth boarding and exiting of the cars. Additionally, straps and stanchion poles to secure the safety of standing passengers and baggage racks to put baggage on shall be installed. The sizes and installation positions shall be determined by considering the average physical size of the Vietnamese people.

(7) Bogie

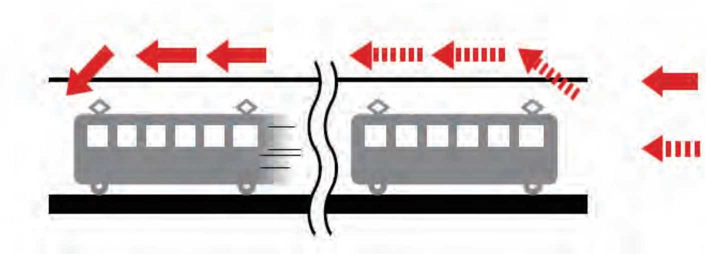
The bogie is equipment with the important role of supporting the weight of the car, transmitting the rotation of the motor to the wheels, and stopping the car using the brakes. In Japan, bolsterless bogies are often employed to save weight, and STRASYA also employs the bolsterless bogie as its standard. However, since the effect of the hot and humid climate in Vietnam to the air springs has not been confirmed, the bolster bogie, which imposes less of a burden on the air springs and is more reliable, shall be employed in consideration of safety and maintenance costs.

(8) Control system and brake system

The control and brake systems can function cooperatively to transmit commands of the train driver and ATO (automatic train operation) system to the motors and mechanical brake system accurately for smooth acceleration and deceleration.

The control device shall be a VVVF inverter control device to control the motors by changing the voltage and frequency after converting the DC power source of 1,500 V from the overhead line to AC power. Additionally, the train set shall have multiple control devices in order to enable the deadhead to the depot even if one device fails.

The brake system shall be all electric command brake equipment. The electric brake shall be a regenerative brake system, and the mechanical brake generated by the force of compressed air shall be a tread brake system. Although both electric and mechanical brake systems are used simultaneously, power consumption and wear on the brake shoes can be reduced by preferentially using the regenerative brake system. Additionally, a security brake shall be installed to brake the running car in the event the service brake equipment fails.



Regenerative electric power is used at the time of acceleration.

The electric power generated at the time of braking is returned to overhead contact line.

Source: JICA Study Team

Figure 3.2.7 Flow of regenerative brake

(9) Other major devices and equipment

In addition to the items above, the major devices and equipment that will be installed on the car are as follows. All of them have been commonly employed for rolling stock in recent years.

1) Current collector

Because the current collection method used for Line 5 is the catenary system, the current collector shall be pantographs. Although there are several pantograph shapes, the latest single arm type shall be adopted in terms of easy maintenance.

Source: JICA Study Team

Figure 3.2.8 Single arm pantograph

2) Auxiliary power supply

The system shall consist of the static inverters and the storage batteries charged by the inverters. The inverters shall convert the DC 1,500 V power source from the overhead line to low-voltage AC power of 440 V and shall supply the AC power to the various systems, such as the motor-driven air compressor, air conditioning equipment and in-car lighting. When the power from the overhead contact line is cut off, the storage batteries can supply power to major systems for 30 minutes or longer.

3) Motor-driven air compressor

This equipment shall generate compressed air for the brake systems, air springs, door operating equipment and other equipment.

4) Air conditioning equipment

An air conditioning equipment that functions as a cooler and dehumidifier shall be installed on the roof of the car, and the control shall be fully automatic. In order to deal with the hot and humid climate of Vietnam, the capacity of the system pee car shall be 72.0 kW (62,000 kcal/h). Note that the system shall not include a heater because the period when it is necessary is short in Hanoi.

5) In-car guidance indicator

Liquid crystal displays shall be used for the automatic display about guidance of the next station and transfer, etc. In addition to guiding for traffic, they can be used as digital signage to display advertisements with video, still images, and other information. Furthermore, train destination indicators using LEDs shall be installed on the front and side of the railway car exterior.

6) Public address system

The system is used to announce the next station and the arrival station, as well as to issue instructions from the train driver in order to guide passengers in the event of an emergency. Since the information is presented through the automatic announcement system by playing recorded data, announcements in foreign languages, such as in English, are possible, in addition to announcements in Vietnamese.

7) Emergency alarm device

This device allows a passenger to communicate with the crew in the cab when a problem or an urgent case occurs in the car.

Source: JICA Study Team
Figure 3.2.9 In-car guidance indicator

Source: JICA Study Team
Figure 3.2.10 Emergency alarm device

3.2.3 Compatibility with other lines

For the urban railway in Vietnam, such as Hanoi Line 2 in which Japan is involved, cars based on the design philosophy of STRASYA are scheduled to be introduced. Therefore, in consideration of future direct operation between different railways, Line 5 shall also be compliant with the STRASYA specification mainly about rolling stock gauge, clearance gauge, and principal car dimensions. However, for items that do not require consideration of the relationship with other lines, those suitable for Line 5 shall be adopted.

Table 3.2.6 Principal dimensions of Urban Railway Lines in the city of Hanoi

Line	Length between couple heads	Car body width	Distance between two bogies	Number of doors	Gauge	Power collection system, Voltage
Line 1	20,000 mm	3,380 mm	13,800 mm	4	1,000 mm 1,435 mm	Overhead line AC 25,000 V
Line 2	20,000 mm	2,950 mm	13,800 mm	4	1,435 mm	Overhead line DC 1,500 V
Line 2A	19,000 mm	2,800 mm	12,600 mm	4	1,435 mm	Third rail DC 750 V
Line 3	19,700– 20,000 mm	2,750– 3,000 mm	11,000– 13,000 mm	4	1,435 mm	Third rail DC 750 V
Line 5	20,000 mm	2,950 mm	13,800 mm	4	1,435 mm	Overhead line DC 1500 V

Source: JICA Study Team

3.2.4 Others

(1) Concept regarding reliability

Line 5 is expected to be operated under high transport density. If the train schedule delays due to vehicle breakdown, it takes a long time to return to normal operation and causes passengers many problems. This also might result in the loss of trust in an urban railway. In order to avoid such situations and to provide stable service, the impact of vehicle breakdown shall be minimized by adopting high-quality cars and equipment. Moreover, each equipment shall be equipped with backup function mutually so that the train operation can be continued in the event of a failure.

(2) About safety

In an urban railway, security against accidents, such as rear-end collisions, frontal collision, etc., is ensured by the signal system. Additionally, the intersections of Line 5 and road traffic shall be solid crossings; therefore, there will be no rail crossing accidents. However, by considering all possibilities, the forefront of the car shall have sufficient strength to withstand a collision. Furthermore, many parts, such as straps and stanchion poles that will be held by passengers, shall be installed in the car to prevent accidents inside the car in the event of emergency braking.

In order to prevent the train fires, electric wires coated with noncombustible or fire-retardant material shall be used to prevent ignition caused by arcing or confused current. Moreover noncombustible or fire-retardant materials shall be used for the interior trim, such as lining, ceiling, floor mat, etc., in the railway car, to prevent the spreading of fire. Fire extinguishers shall be installed in the car for initial fire extinction in case of fire.

Traffic data recording system shall be installed on the rolling stock in order to use for the investigation of the cause and prevention of the recurrence in case of an accident.

(3) About barrier-free

Improvement in public transportation systems has the effect of promoting the transport of people without transportation, such as a bike. Since people who are elderly or disabled are included, the cars shall be designed in consideration of convenience and safety. The major equipment is listed below:

1) Wheelchair Space

At least one space for a passenger in a wheelchair shall be prepared in each formation. An emergency alarm device that allows the passenger to communicate with the crew shall be installed near the space.

Source: JICA Study Team

Figure 3.2.11 Wheelchair space and priority seat

2) In-car guide display system

For passengers who are hearing impaired and cannot hear in-car announcements, this system informs them of the current position, the information about transfer at the next station, etc., using a liquid crystal display.

3)Priority Seat

Priority seats shall be installed in each rolling stock for people who are elderly, disabled, and pregnant and for people with small children.

(4) The period of time during which rolling stock performs its function efficiently and major refurbishment work

The service life of a railway car can be lengthened with a life cycle of 40 to 50 years or longer. Additionally, the car shall require periodic inspection, as well as updates to the major equipment, such as the control device and installation of new electric lines. Therefore, the rolling stock shall require major refurbishment work about 20 to 25 years after construction. However, the service life and the details of the major refurbishment work are closely related to the lease period, service for passengers and risk management; therefore, it is desirable that a comparison and examination shall be carried out about the options that can best reduce operating costs on the premise that the rolling stock will be refurbished in about 15 years or so.

Table 3.2.7 The total number of years that rolling stock can be used and its influence
(By way of examples)

	Case 1	Case 2	Case 3
The total number of years	25 years	50 years	50 years
Time of major refurbishment work	None	None	25 years
Riskiness of breakdown	○	×	△
Availability of parts of rolling stock	○	△	△
Maintainable	○	×	△
Service for passengers	○	×	○
Image	○	×	△
Cost of new manufacturing and refurbishment work	×	○	△

Source: JICA Study Team

《Legend》 ○: Good △: Poor ×: Bad

3.3 Operation Plan

3.3.1 Basic concept

In principle, for the train operation schedule, the operational interval of trains and the number of cars in formation shall be considered based on the results of the demand forecast described above.

Although there is a concept to emphasize the convenience of railways by shortening the operational interval in order to make the use of the railway into a habit and to promote the transition from other means of transportation, for a time after the line opens, without excessively adhering to the results of the demand forecast. In this study, the operation schedule shall be considered based on the results of the demand forecast.

As for passenger service, it is important to ensure punctuality. In Japan, train operation is very strict about time by monitoring the train delays in units of 10 seconds. This strictness about time cultivated in Japan shall be introduced to Line 5.

3.3.2 Precondition for operation planning

(1) Train operation speed

The maximum operation speed shall be 120 km/h for the elevated zones and on-ground zones where the simple catenary overhead line is used. The reason for the value above is as follows. In the study, the maximum operation speeds between 120 km/h and 160 km/h were considered. As a result, it was confirmed that quick-deliverability can be secured with a speed of 120 km/h.

As for the speed limit for turnouts, all the turnouts introduced to the main section of the Line 5 are No. 12. Therefore, the transit speed at the branch side of a turnout on the main line shall be 45 km/h. The speed limits for falling gradients and curves shall be as shown in the tables below:

Table 3.3.1 Speed Limit for Falling Gradient

Down gradient	Speed
20/1,000 or less	100 km/h
30/1,000 or less	90 km/h

Source: JICA Study Team

Table 3.3.2 Speed Limit for Curve

Curvature radius	Speed
800 m or longer to less than 1,000 m	110 km/h
1,000 m or longer	115 km/h

Source: JICA Study Team

(2) Margin time

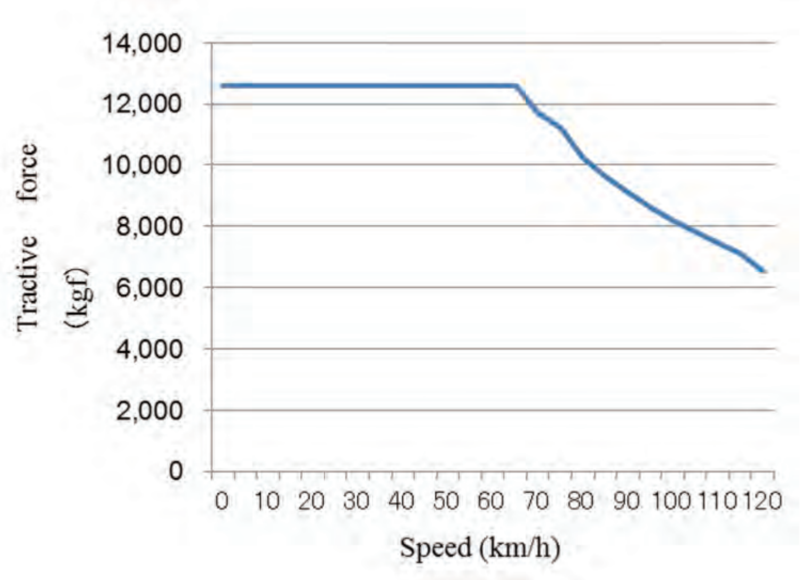
A train performance diagram shall be created using the maximum operation speeds minus 5 km/h. However, the speed limits for turnouts, falling gradients, and curves shall be created using the same speeds as the speed limits. When the train performance diagram is created as described above and the train schedule is created using the calculated running times, the schedule includes margin times, and as a result, punctuality can be easily secured.

(3) Stopping time

The train schedule shall be created using a stopping time at each station of 30 seconds. After the train arrives at a station and the platform doors open, the doors of the train open and passengers get on and off. When all passengers have entered and exited the train and the doors are closed, the platform doors close so the train can pull away from the platform. For the passengers to get on and off safely, a stopping time of 30 seconds shall be ensured.

(4) Running performance

The running performance of a train as shown in the graph below was used. Because the distances between stations in the suburban area are short, running performance that allows high acceleration and high deceleration is assumed to increase operational efficiency.



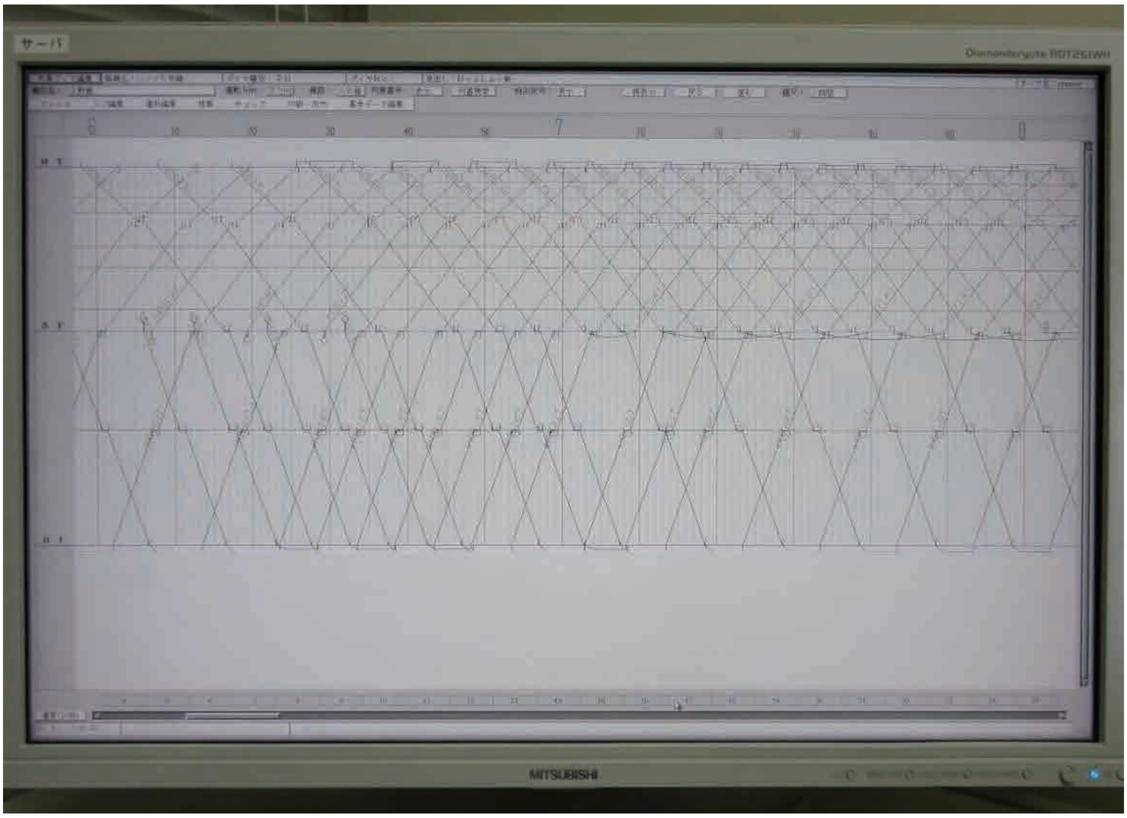
Source: JICA Study Team

Figure 3.3.1 Relationship between speed and tractive force

3.3.3 Consideration of operation plan

(1) System used

When creating a train performance diagram and train schedule, the Keihan computer system to make timetables, ASK (Advanced system of diagram Simulation for Keihan), was used. Making them by utilizing the system of another company, Study Team compared the diagrams and schedules made by the two systems, but there was no significant difference between them.



Source: JICA Study Team

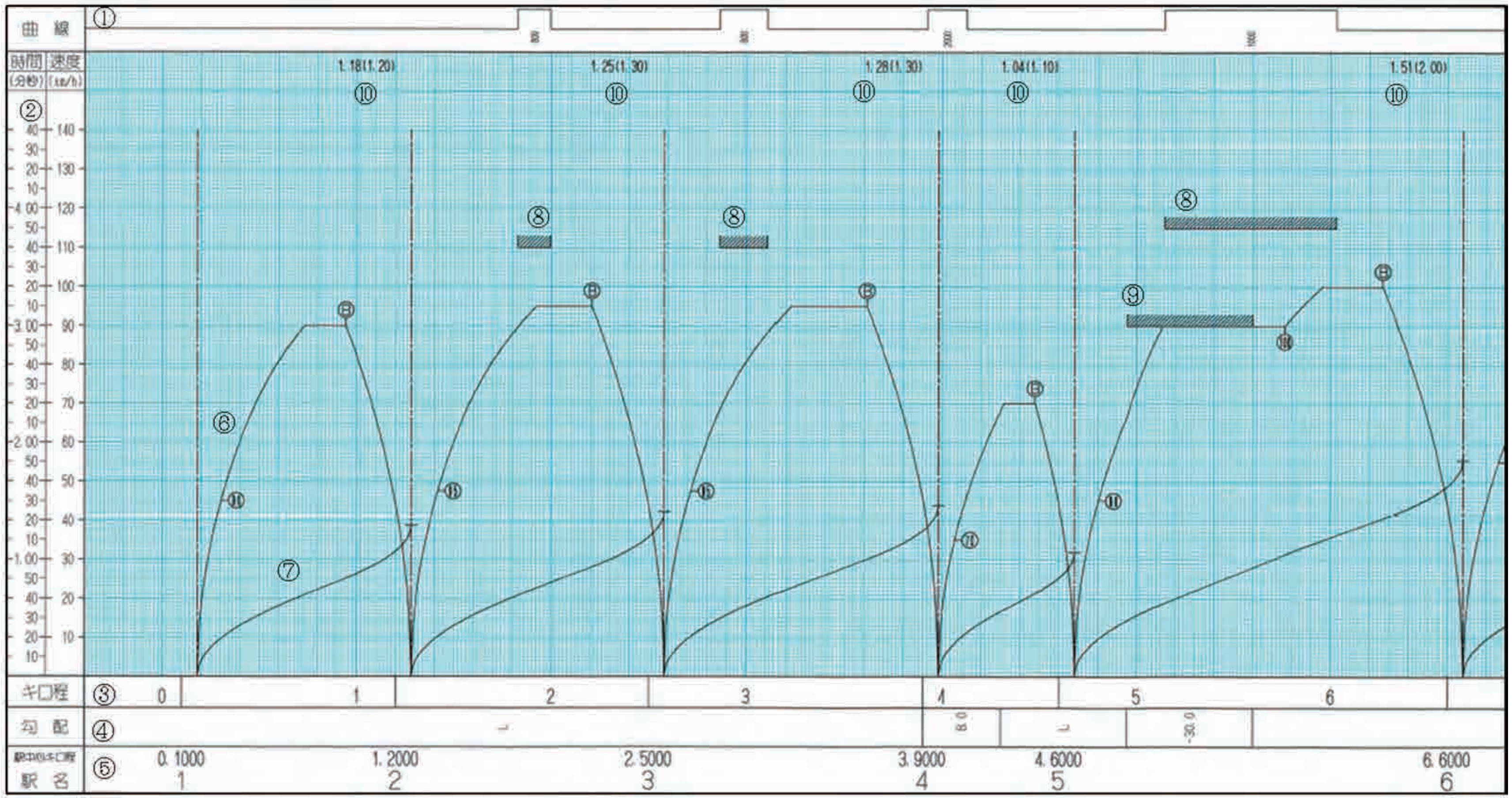
Figure 3.3.2 Keihan computer system to make timetables “ASK”

(2) Train performance diagram

A train performance diagram shows the relationship of running distance, speed and time in consideration of train performance and train resistance. This diagram is used to calculate the running time as the basis for the train schedule. In general, a diagram whose abscissa indicates distance, the ordinate indicates speed, and time is used, then the speed and elapsed time of train at an arbitrary running distance can be easily obtained from it.

It is planned to prepare train sets of four cars for inauguration of the Line 5, then the number of cars will be increased to 6 and to 8 per train set with the increase in demand. Since the length of train set differs when the number of cars differs, for example, the influence by gradient and the distance that a train runs with limited speed are changed. As a result, train performance diagram becomes different in some degree as well.

When making the train performance diagram of the Line 5, a four-car train set was assumed for 2021 (when Phase 1 opens) and an eight-car train set for 2030 (when Phase 2 opens), by considering the possible utilization of four-car, six-car, and eight-car train sets. Figure 3.3.3 shows train performance diagram made for reference. This diagram indicates the performance from St.1 to St.5 in 2030 (When Phase 2 opens) with an eight-car train set in case of elevated structure. The train performance curve diagrams for each train set were made in consideration of differences in train formations. However, as shown in Tables 3.3.3 and 3.3.4, there were almost no differences between the running times of St. 1 to St. 10 in the two cases.



Source: JICA Study Team

Figure3.3.3 Train Performance Diagram (St. 1 - St. 5) in 2030 (when Phase 2 opens)

The items shown on a train performance curve diagram are as follows.

① Curve and curvature radius, ② Running time and speed, ③ Kilometerage, ④ Gradient, ⑤ Kilometerage at station center and station name, ⑥ Speed curve, ⑦ Time curve, ⑧ Speed limit for curve, ⑨ Speed limit for down gradient, ⑩ Drawing time and appraised time

Table 3.3.3 Running Time in 2021 (when Phase 1 opens)

No.	Station Name	Running direction ↓		Running direction ↑	
		Drawing	Appraised	Drawing	Appraised
1	Ho Tay				
		1.18	**1.20**	1.26	**1.30**
2	Kim Ma				
		1.25	**1.30**	1.25	**1.30**
3	Lang Trung				
		1.28	**1.30**	1.28	**1.30**
4	Trung Kinh				
		1.04	**1.10**	1.02	**1.10**
5	Trung Hoa				
		1.51	**2.00**	1.49	**1.50**
6	Me Tri				
		1.41	**1.50**	1.41	**1.50**
7	Giao Quang				
		1.50	**1.50**	1.46	**1.50**
8	Tay Mo				
		1.21	**1.30**	1.25	**1.30**
9	An Tho				
		1.51	**2.00**	1.41	**1.50**
10	An Khanh	↓		↑	
	Running Time 30 seconds of stopping time included for each station	**18 minutes 40 seconds**		**18 minutes 30 seconds**	

Source: JICA Study Team

* Time between stations calculated from a train performance curve diagram is called "Drawing Time," and time rounded up in units of 10 seconds when making a train schedule is called "Appraised Time."

Table 3.3.4 Running Time in 2030 (When Phase 2 opens)

No.	Station Name	Running direction ↓		Running direction ↑	
		Drawing	Appraised	Drawing	Appraised
1	Ho Tay				
		1.18	**1.20**	1.26	**1.30**
2	Kim Ma				
		1.25	**1.30**	1.25	**1.30**
3	Lang Trung				
		1.28	**1.30**	1.28	**1.30**
4	Trung Kinh				
		1.04	**1.10**	1.02	**1.10**
5	Trung Hoa				
		1.51	**2.00**	1.49	**1.50**
6	Me Tri				
		1.41	**1.50**	1.41	**1.50**
7	Giao Quang				
		1.50	**1.50**	1.46	**1.50**
8	Tay Mo				
		1.21	**1.30**	1.25	**1.30**
9	An Tho				
		1.41	**1.50**	1.41	**1.50**
10	An Khanh				
		1.11	**1.20**	1.10	**1.10**
11	Song Phuong				
		3.53	**4.00**	3.52	**4.00**
12	Quoc Oai				
		2.25	**2.30**	2.25	**2.30**
13	West Quoc Oai				
		4.57	**5.00**	4.56	**5.00**
14	Hoa Lac				
		2.15	**2.20**	2.12	**2.20**
15	Tien Xuan				
		1.50	**2.00**	1.49	**1.50**
16	Trai Moi				
		1.45	**1.50**	1.35	**1.40**
17	Ba Vi	↓		↓	
Running Time 30 seconds of stopping time included for each station		**41 minutes**		**40 minutes 30 seconds**	

Source: JICA Study Team

(3) PPHPD at peak time and off-peak time

When making a train schedule, the operational interval shall be established so that the schedule can completely deal with the number of passengers in one direction per hour at peak times, that is, PPHPD (passengers per hour per direction). According to the results of the demand forecast (Origin-Destination (OD) data), PPHPDs at peak times and off-peak times are calculated as follows:

Table 3.3.5 PPHPDs at Peak Times and Off-peak Times by Year

Year	Apportionment ratio	Concentration ratio	PPHPD at peak time
2021 (when Phase 1 opens)	10%	20%	8,320 passengers
2030 (when Phase 2 opens)	15%	20%	13,345 passengers

Source: JICA Study Team

(4) Train diagram

A train diagram is a diagram that represents the operation plan of the train. In general, the abscissa is time and the ordinate is distance, and station names are located on the ordinate. The movements of all trains in a day can be understood from the schedule.

In this study, the train schedule was considered based on the results of the demand forecast. In addition, Study Team set peak times in the morning as around 7:00 to 9:00 AM and in the evening as around 4:30 to 6:00 PM.

1) Year 2021 (when Phase 1 opens)

Phase 1 is scheduled to open in 2021, and based on the results of the demand forecast, about 171,000 passengers are expected to use the line every day including the passengers from connecting lines, thus PPHPD at peak times was 8,320 passengers.

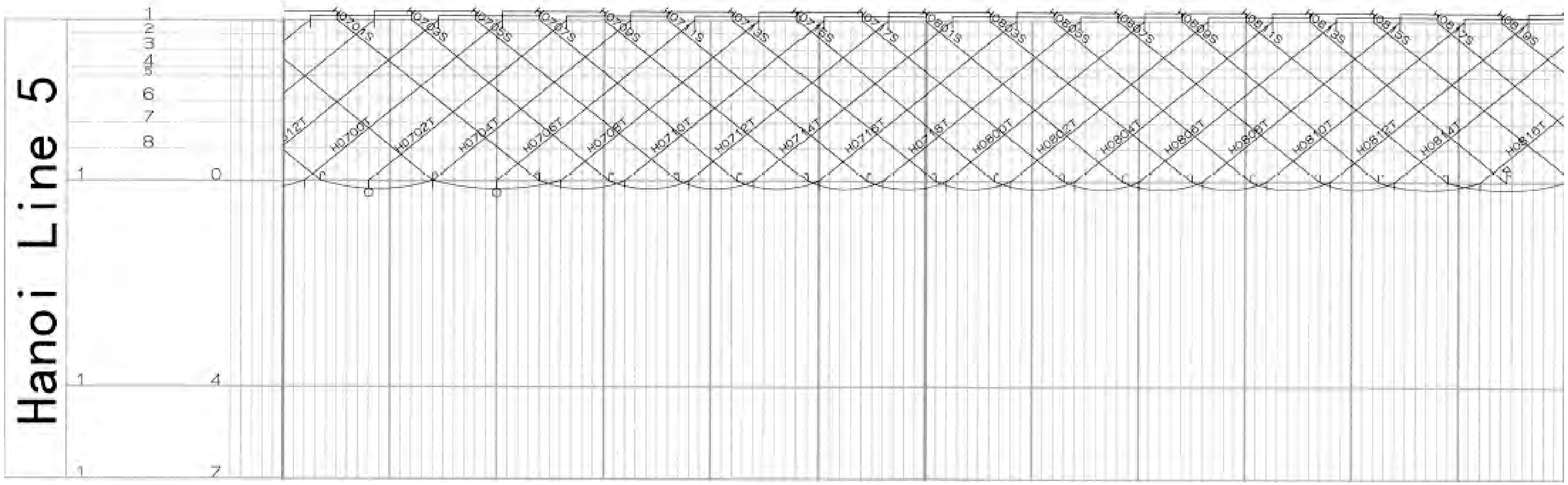
After opening, Phase 1 is scheduled to operate four-car train sets. The reasons for this formation are that it is enough to deal with the forecasted demand, and the cost of train and electricity increases if longer trains are used. Operations with shorter trains are desirable because train drivers would not be familiar with operations just after Phase 1 opens, and this may lead to accidents in which passengers are caught in the doors.

The operational intervals at the time of inauguration are six minutes for morning peak times and 12 minutes for daytime.

As for the number of train sets required, the number must be determined to deal with the passengers during morning rush hours when the number of passengers is highest for the day. The number of train sets required can be calculated using the following formula:

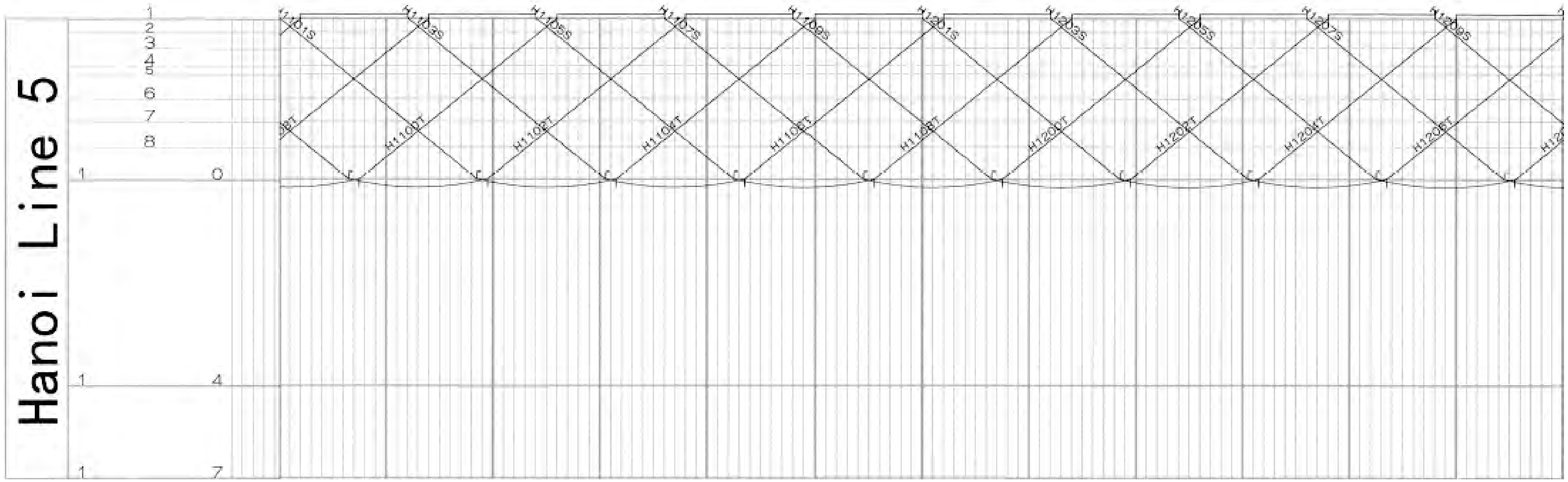
$$\text{(Number of train sets)} = \frac{\substack{\text{Round trip time} \\ \text{(including waiting time at the turn-around station)}}}{\text{Operation interval}} = \frac{3{,}240}{360} = 9 \text{ (train sets)}$$

Therefore, nine train sets are required for operations during a single day. In addition, two sets shall be added to this value as backup for failure or inspection. The total number of sets is 11 with 44 cars. The cars shall be prepared by the time the line is open.



Source: JICA Study Team

Figure 3.3.4 Train diagram of the morning peak times in 2021 (when Phase 1 opens)



Source: JICA Study Team

Figure 3.3.5 Train diagram of the daytime in 2021 (when Phase 1 opens)

2) After Year 2030 (when Phase 2 opens)

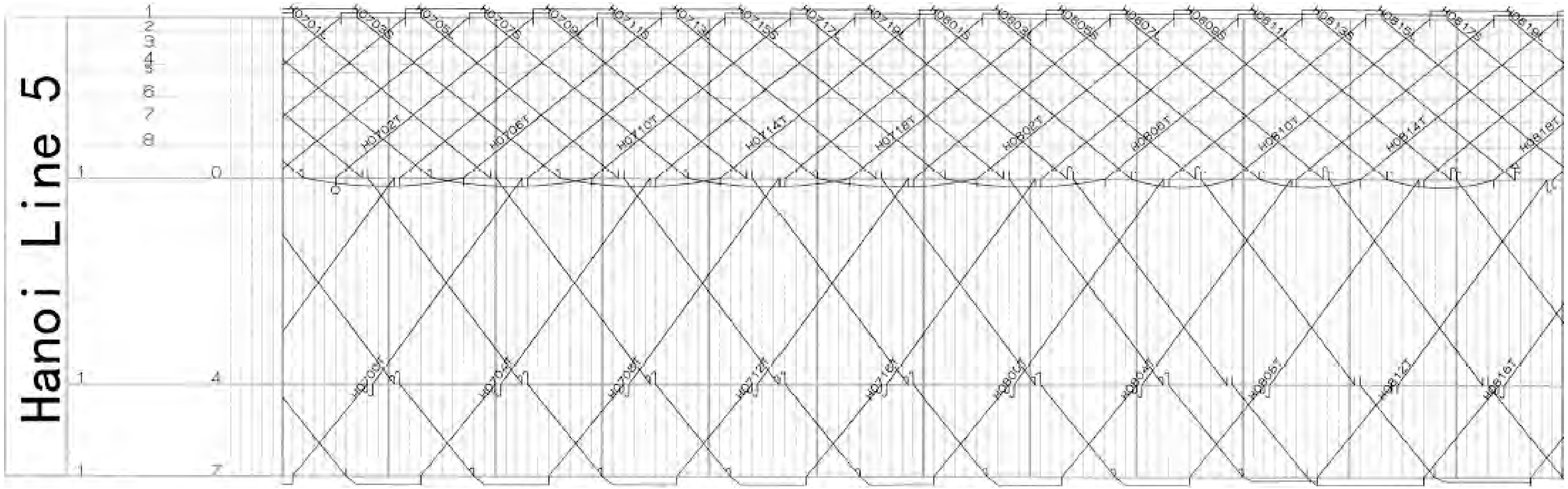
In 2030, about 432,000 passengers are expected to use the line every day including the passengers from connecting lines,, thus PPHPD at peak times is 13,345 passengers. Assuming the number of cars in one train set as 6 cars when Phase 2 opens, it is planned to reinforce transportation capacity. After the inauguration, it is possible to increase the capacity by shortening operational interval or increasing the number of cars per train set into 8 cars in order to cope with increase in demand.

At peak hours, the operational interval in urban area of Hanoi city is six minutes while that in St. 10 to St. 17 is 12 minutes even at peak times as demand is lower in comparison with Hanoi city center. Thus, the transportation capacity between St. 1 and St. 10 shall be increased by operating both trains for St. 1 through St. 10 and trains for St. 1 through St. 17 during peak times. In order to realize such operational interval, the train diagram is made assuming that trains for St. 1 through St. 10 and trains for St. 1 through St. 17 are operated alternately at interval of 12 minutes at rush hours. The number of train sets required can be calculated using the following formula:

$$\text{(Number of train set)} = \frac{\text{Round trip time for St.1 to St.10}}{\text{Operation interval for St.1 to St.10}} + \frac{\text{Round trip time for St.1 to St.17}}{\text{Operation interval for St.1 to St.17}}$$

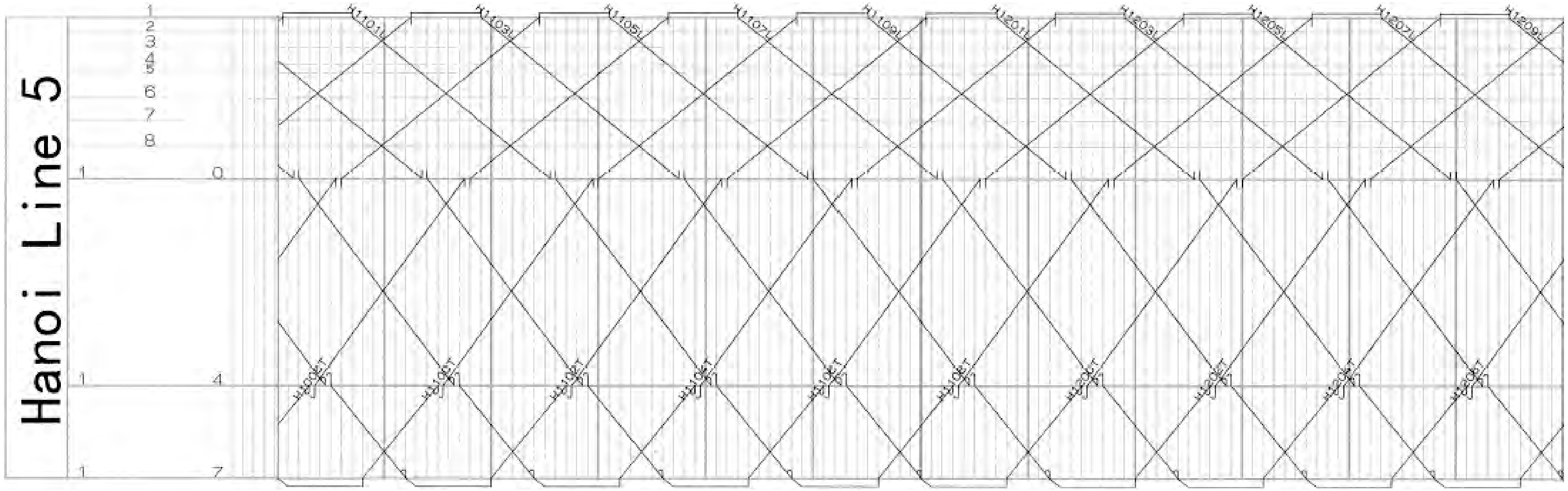
$$= \frac{3{,}600}{600} + \frac{4{,}200}{600} \fallingdotseq 14 \text{ (train sets)}$$

However, it is figured out that the number of train sets required is 13 after Study Team made train diagram. It is considered this is because the setting of peak hours is short. Therefore, two sets shall be added to this value as backup. The total number of train sets required is 15 with 90 cars.



Source: JICA Study Team

Figure 3.3.6 Train diagram of the morning peak times after 2030 (when Phase 2 opens)



Source: JICA Study Team

Figure 3.3.7 Train diagram of the day time after 2030 (when Phase 2 opens)

3) Supplemental note

The actual demand is expected to be less than the forecast even if the operation plan is established as consistent with the results of the demand forecast. However, the transportation capacity will not be reduced immediately by reducing the number of trains to conform to actual demand. The frequency will be ensured to improve the convenience of passengers. When Line 5 opens in 2021, it will not be long after an urban railway will be introduced to the city of Hanoi, and the residents might not be accustomed to using a railway. In consideration of this, the first goal shall be to promote the urban railway. And then encourage people to shift their means of transportation from motorcycles, cars, and bicycles to the railway.

3.3.4 Extraction of issues

(1) Saturday and holyday schedule

Regarding Japanese railway, there is a difference in number of passengers between weekday and Saturday and holyday since people have different life style. As most of the people who go to companies and schools use trains at the same period of time in Japan, there are many passengers utilizing railway in the morning peak hours on the one hand. On the other hand, however, since most of companies and schools set Saturday and Sunday as holydays, demand for railways in holiday is not so much as that of weekday. Therefore, most of the Japanese railway companies prepare two types of train operation schedule for weekday and holiday, and reduce number of trains to operate in Saturday and holiday. By setting the Saturday and holiday schedule, the companies are able to achieve reduction in operation staff and electric power saving.

When Line 5 starts operation, it seems better to operate the line with the same train schedule every day without setting the Saturday and holiday schedule when the line opens. The reason for this is that the use of railway becomes habitual by operating the trains at the same times every day. Additionally, buses currently operated in the city of Hanoi use the same operation schedule for weekdays, Saturdays, and holidays. The Line 5 should comply with this practice.

(2) Express train and local train

The train schedule with the number of current stations was created by assuming that the maximum operation speed is 120 km/h, and it was then revealed the interval between Ho Tay and Hoa Lac can be operated in around 33 minutes. However, if the developer requested to add stations in the future and then stations are added, it will be difficult to maintain the quick-deliverability using only local trains. In this case, two types of trains, or express trains and local trains, should be operated if it is necessary to secure the quick-deliverability.

In order to realize the connection from express trains to local ones, two platforms with four tracks are necessary, but they cannot be located within the width of the center divider along Thang Long road. Therefore, the facilities to overtake trains departed before are required. As for structure of station with passing track, refer to 3.4.8 (1).

(3) Manner of passengers getting on and off during rush hours

Since there is no urban railway in the Hanoi city now, it is thought that education related to the manner of boarding and exiting cars must be taught to the citizens to coincide with the opening of the railway. If it takes too long time for boarding and exiting, this leads to delays. Additionally, there is a risk of problems between passengers. To achieve boarding in lines as in Japan in the city of Hanoi, it is thought that the city of Hanoi must play a central role in the teaching of the proper etiquette.

(4) Woman-only car (for reference)

By some Japanese railway operators, rolling stocks with a women-only car have been introduced as part of transport service. Some long-distance night trains had a rolling stock or some seats which were exclusively for woman before. Recently, with passenger’s understanding and cooperation, as one of efforts by railway operators, the number of railway operators which introduce rolling stocks with a women-only car during commuting hours is increasing. In Vietnam, wide discussion is required about the introduction, especially on whether it becomes familiar with the Vietnamese society or whether people's understanding can be obtained.

3.4 Plan of civil engineering facilities

3.4.1 Results of the study on geological features along the Line 5

Based on the documents obtained, a geological profile of the Line 5 was created as shown in Figure 3.4.1. The research documents of 10 locations over the whole line were picked up. Here, discussions on three zones—(1) origin to about 15 km, (2) about 15 km to about 30 km, and (3) about 30 km to the end—are made as follows.

(1) Origin to about 15 km

In this zone, a relatively loose sand layer and a clay layer are piled up from the surface to around 40 m in the ground. The N value of the sand layer is about 7 to 26 and there is a tendency for the value to increase along with the depth. The N value of the clay layer is about 6 to 20, and there is also a tendency for the value to increase along with the depth. Under these layers, there is a gravel layer with an N value of 50 or higher.

When the line is elevated, the piers require support by piles. It is thought an adequate bearing layer is the gravel layer. In this case, it is supposed that the extension length of pikes is about 40 m.

When the line runs underground, the tunnel is dug through the sand and clay layers near the surface. Judging from the N values only, the cut and cover method or shield tunneling method will be suitable for this case. In contrast, it is thought that the ground is not suitable for the new Austrian tunneling method (NATM).

(2) About 15 km to about 30 km

In this zone, a clay layer with a depth of around 30 m covers the surface. The N value of the clay layer is about 5 to 30. However, the relationship between the depth and N value varies over the survey points and lacks consistency. Although the layer is not weak, it is hard to say it is good ground. The layer below is a sand layer with gravel or a consolidated clay layer depending on the location.

When the line runs over an embankment, it is thought that a consolidation measure is required. For proper judgment, research is required before the design for execution.

(3) About 30 km to the end

In this zone, a hard clay layer lies relatively near the ground. However, the research was not done in a deeper location. Therefore, research is required before the design for execution for proper judgment.

When the line runs over an embankment, since there is a hard clay layer near the ground, it is thought that the embankment body could be constructed with relatively little effort.

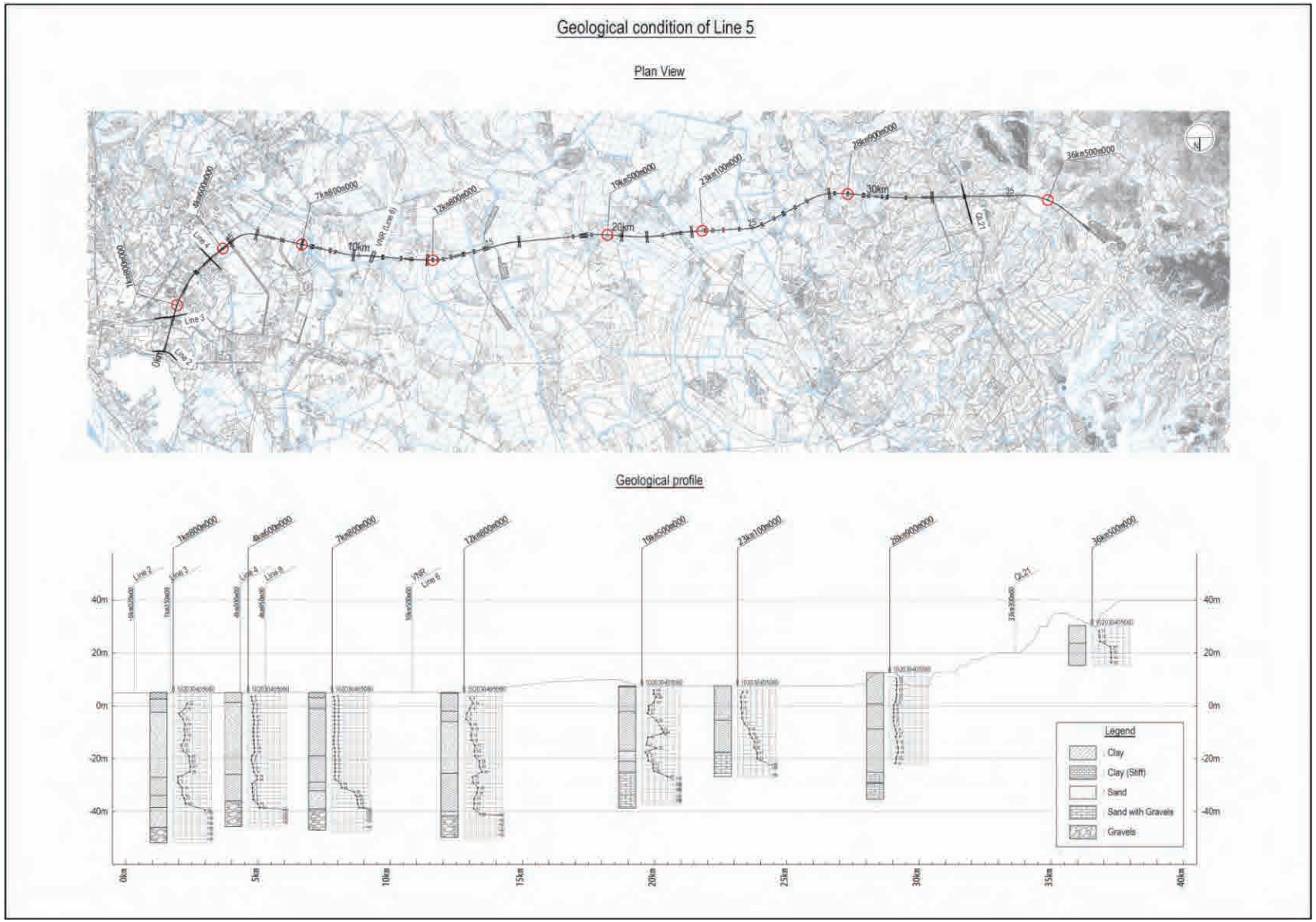


Figure 3.4.1 Geographical condition

Source: JICA Study Team

3.4.2 Technical standards

The technical standards used for this research are set as follows in compliance with the document "Support for Establishment of Technical Criterion and Standards for Vietnam's Railway – June 2009 Japan International Cooperation Agency" and other documents.

These standards relate to the Line 5 and aim to contribute to the development of urban railways by defining basic specifications; securing safety; considering economic efficiency, convenience, and comfort; and improving the smoothness and efficiency of transportation, as well as the quality of travel services. In this case, the following points are studied specifically.

Table 3.4.1 Major technical standards

Items	Value
ALIGNMENT PROFILE	
Minimum radius of curve	The value required for safe train operation at setting speed
Minimum radius of curve for the branch line to Depot	200m
Minimum radius of curve for Depot area	100m
Type of transition curve	Clothoid or 3 dimentional curve
Maximum vertical gradient	
- When not considering curve resistance	30(permil)
- When considering curve resistance	35(permil)
Minimum vertical gradient	2(permil) except for elevated stations
Minimum radius of vertical curve	
- radius of curve>=800m, without restrictions	3000m
- radius of curve>=800m, with restrictions	2000m
- radius of curve<800, without restrictions	4000m
- radius of curve<800, with restrictions	3000m
TURNOUT & SLEEPER	
- on Main line	#12
- on Depot area	#8
Sleeper	PC sleeper
PLATFORM	
Length of platform	Length of train set + 10m
Width of platform	Enough width for aisle and elevators/escalators

Source: JICA Study Team

3.4.3 Outline design of urban civil engineering facilities (for elevated structure)

(1) Outline

The outline when the line has an elevated structure in the midtown (within 5 km from its origin) is as follows. First, the elevated general zone is a girder structure that has a simple structural form and allows the efficient use of an elevated structure and landscape measures by planting. Additionally, the stations have a rigid-frame structure to realize economic design, and this allows securing a lot of space for safety and disaster prevention, as well as multipurpose use, including commercial use. However, a part of the line requires a special elevated structure due to road conditions, and the result of the study on the part is described below.

Source: JICA Study Team

Figure 3.4.2 Elevated station in the midtown area (image)

Source: JICA Study Team

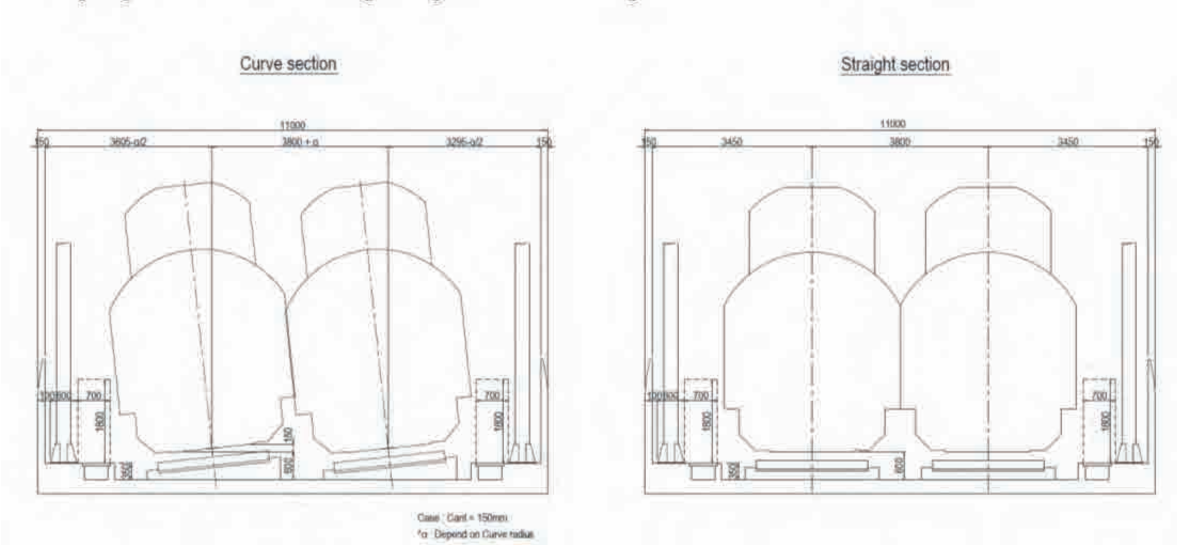
Figure 3.4.3 Elevated station in the midtown area (image)

Source: JICA Study Team

Figure 3.4.4 Vicinity of the National Conference Center (image)

(2) Standard section of elevated general zone

The total width of the viaduct shall be set as shown in the figure by considering the clearance gauge, refuge space, administrative passage, and column space.



Source: JICA Study Team

Figure 3.4.5 Drawings of the width of formation level

(3) Type of viaduct

The type of viaduct shall be selected by considering (i) economic efficiency, (ii) workability, and (iii) landscape. According to the survey at the site, there are many actual examples of RC girders and PC girders, but there are few steel girders. There is a possible concern about noise from steel girders, thus this line shall use RC girders and PC girders for the ordinary viaducts in the plan. Because a rigid-frame viaduct is inferior in terms of workability, it shall be used only for an elevated station.

Furthermore, for the parts where piers cannot be installed because the width of the median strip is insufficient due to the conditions of the road on which the viaduct is constructed, a special bridge structure shall be considered.

1) Girder types for ordinary viaducts

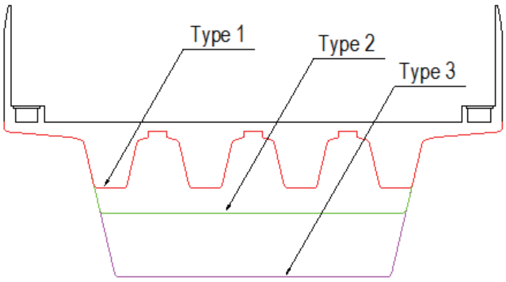
The following three types of girder for ordinary viaducts shall be proposed by considering economic efficiency and workability. It is assumed that these types are used depending on the span length. With the purpose of avoiding field casting, which requires difficult field management, as much as possible, each type shall be able to be manufactured at a factory or at a yard near the construction site.

Type 1 (Span: 20 m or less): PCU girder

Type 2 (Span: 30 m or less): PC box girder

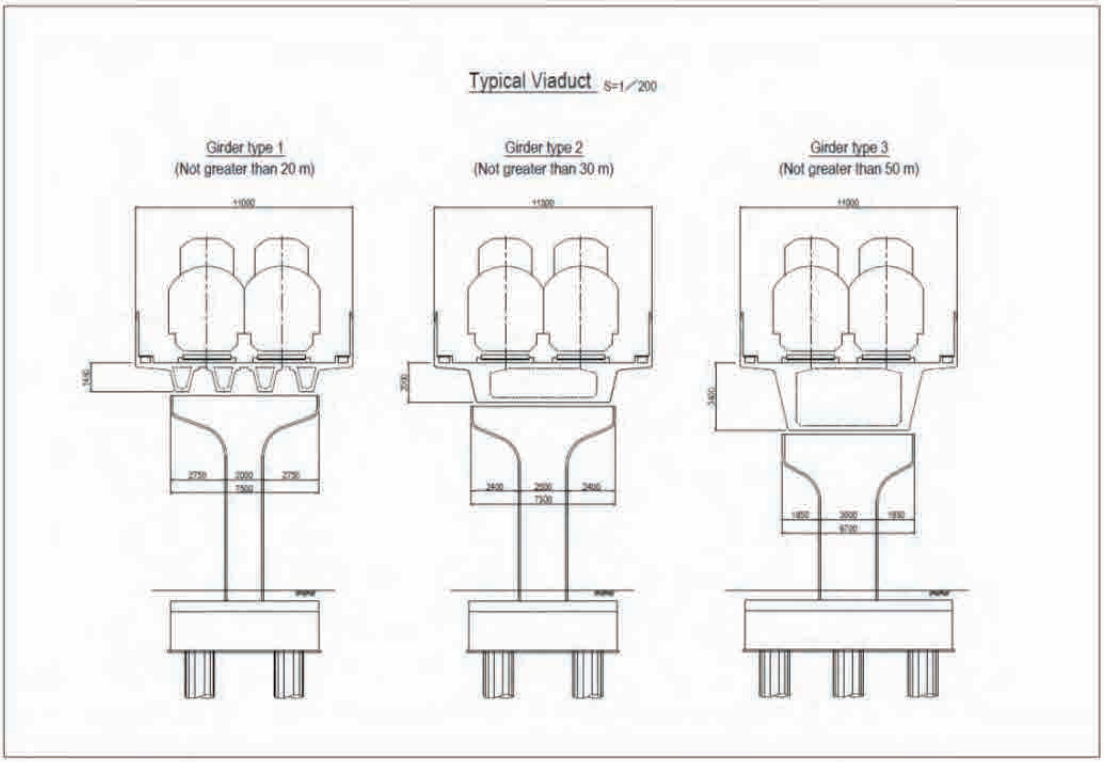
Type 3 (Span: 50 m or less): PC box girder

As shown in Figure 3.4.6, the structures shall be aesthetic by harmonizing the shapes of the overhanging portion of each type and by aligning their side lines to maintain the visual continuity of the structure.



Source: JICA Study Team

Figure 3.4.6 Superimposition of the contours of different type girders

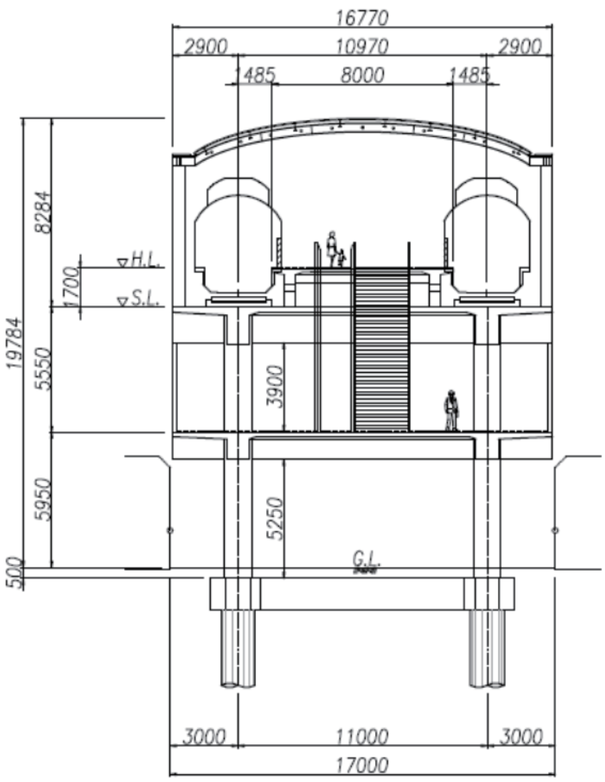


Source: JICA Study Team

Figure 3.4.7 Viaduct girder types in ordinary sections

2) Elevated station part (one platform with two tracks) * from the origin to the Ring Road 3

The structure of the station on this line shall be a rigid-frame structure, and the concourse floor and rail track/platform floors shall be ensured. The platform shall be one island platform with two lines as standard, and it was planned so that the viaduct could be accommodated in the median strip in the midtown area. For the site width, the value that was actually measured at the survey shall be used. According to this plan, the full width can be accommodated in the median strip as shown in Figure 3.4.8.



Source: JICA Study Team

Figure 3.4.8 Elevated station (1 platform with 2 tracks)

3) Special Bridge Part

As described above, the girder type elevated structure at the ordinary viaduct and the rigid-frame viaduct at the station part are general structural forms. However, portal piers are planned for the parts such as St. 2 to St. 3 where the width of the median strip is narrow and the piers are difficult to be installed. Furthermore, it is necessary to consider a very long span bridge for the river bridge near the Ring Road 2 and relatively large intersections between St. 3 and St. 4.

(4) Construction method

As for railway structures, their finished quality is largely affected by the skill levels of mold makers, reinforcing bar workers, and concrete placing workers in the field. If the levels are insufficient, it is difficult to ensure safe operation, and there is a concern about the increase in maintenance costs after the start of operation in many cases.

In consideration of the fact that Vietnam's experiences in the construction of railway structures in recent years is not fully sufficient, the construction method for the viaducts is devised so that the effects are the securement of quality and a reduction in cost in the civil engineering work. These shall be achieved by introducing laborsaving construction methods, such as the use of a guider type in general parts and the use of precast materials for bridge railings, as much as possible. However, there are many structures, such as piles and piers, which must be constructed at the site, thus it is necessary to secure construction management and supervision sufficient for local workers.

3.4.4 Outline design of urban civil engineering facilities (for underground structures)

(1) Outline

The outline when the line has an underground structure in the midtown area (within 5 km from the origin) is as follows. First, the underground structure can generally be divided into two types: the cut and cover method and the shield tunneling method. The application of the construction method largely depends on construction depth. In general, the cut and cover method is used to create a large-scale space, such as a station, and the shield tunneling method is often used to simply secure a section where trains pass through at the parts between stations. Additionally, in order to minimize construction costs, it is usual to reduce the length of the sections using the cut and cover method as much as possible.

The construction methods for this line when the midtown area has an underground structure are as follows:

Table 3.4.2 Construction method of each interval

Station	Interval distance (m)	Construction method	Remarks
St. 1	410	Cut and cover method	Three-layer station part and turnout part
	685	Shield tunneling method	
St. 2	210	Cut and cover method	Three-layer station part
	955	Shield tunneling method	
St. 3	280	Cut and cover method	Two-layer station part
	1,220	Shield tunneling method	
St. 4	280	Cut and cover method	Two-layer station part
	520	Shield tunneling method	
St. 5	280	Cut and cover method	Two-layer station part
	510	Cut and cover method	General part
	510	Cut and cover method	Trench part
Total	5,860	Total distance of the cut and cover method: 2,580 m, the total distance of the shield tunneling method: 3,280 m	

Source: JICA Study Team

Source: JICA Study Team

Figure 3.4.9 Underground station in the midtown area (image)

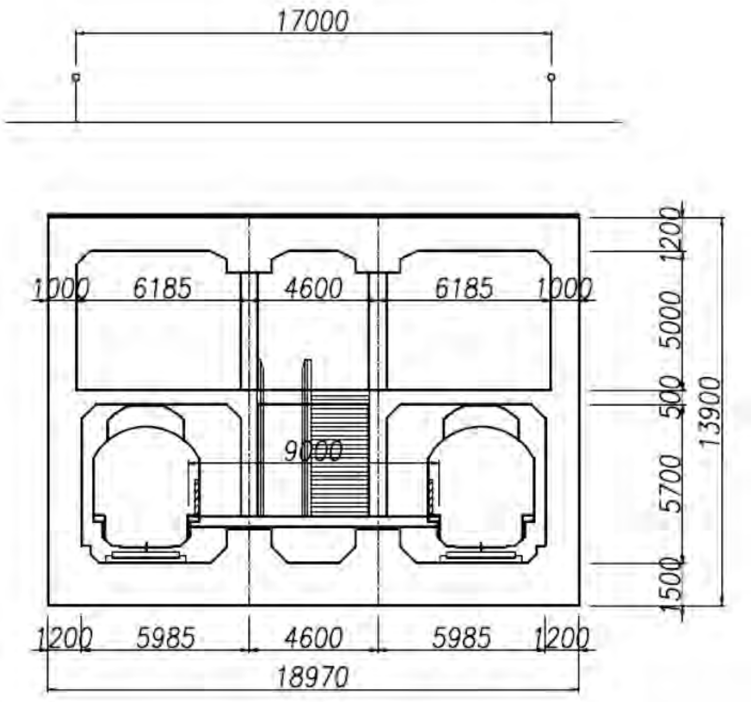
(2) Type of Underground Structure

1) Cut and Cover Part

<Station Part>

The shape of the station is determined by laying out stairs, passages, platforms, and other facilities. The length of cut and cover is the platform length calculated by the length of the train as standard, but it is also necessary to secure space for facilities installed in the underground stations. In particular for a two-layer station, it needs to be noted that facility planning is the determinant factor for the length of cut and cover. Here, the reason that the length of cut and cover in St. 3 to St. 5, for which the two-layer station is planned, is 280 m as follows. These stations require space for placing facilities in the underground station (about 1,000 to 1,200 m^2), and space must be secured on the concourse floor. The length of cut and cover is calculated based on these conditions.

The design sections are calculated continuously using the rigid box-frame structure in the transverse direction as standard, and the earthquake resistant design is done for the representative sections. Furthermore, for the development of buildings around a station and of city planning, a structure that has flexibility is desirable in the sections where it is possible to be connected to the station in the future.

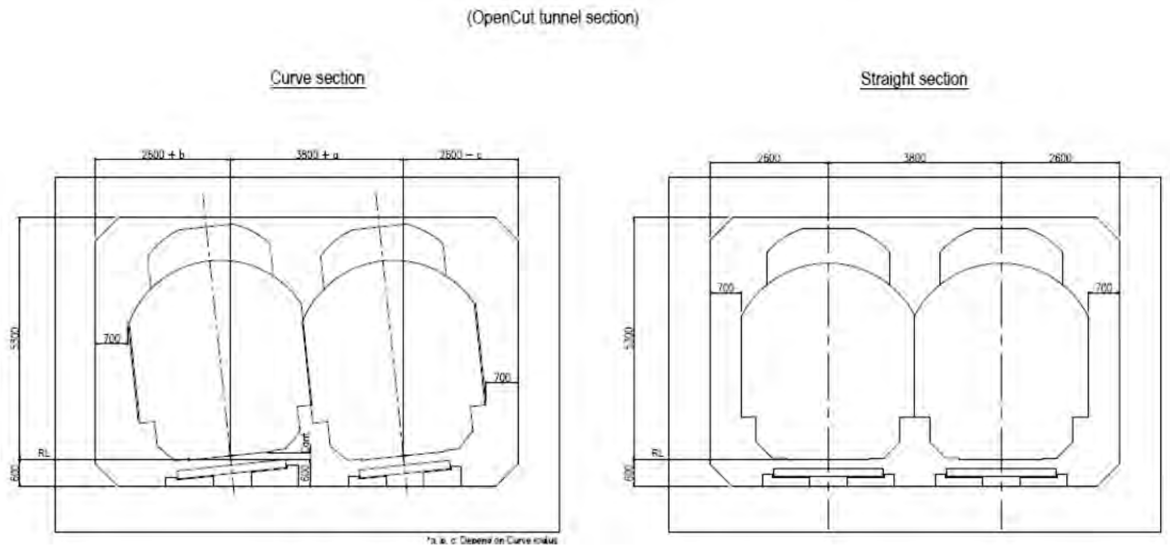


Source: JICA Study Team

Figure 3.4.10 Standard section diagram of cut and cover part (station part)

<General Part>

The cut and cover in the general part shall have a rigid box-frame structure as standard. Although the necessary section shall be the clearance gauge as standard, it is important to secure refuge space supposing the inspection of tracks for maintenance. When there is a post between the rigid box-frames, this space shall be used effectively. When there is no post, however, the section shall be planned by considering this.

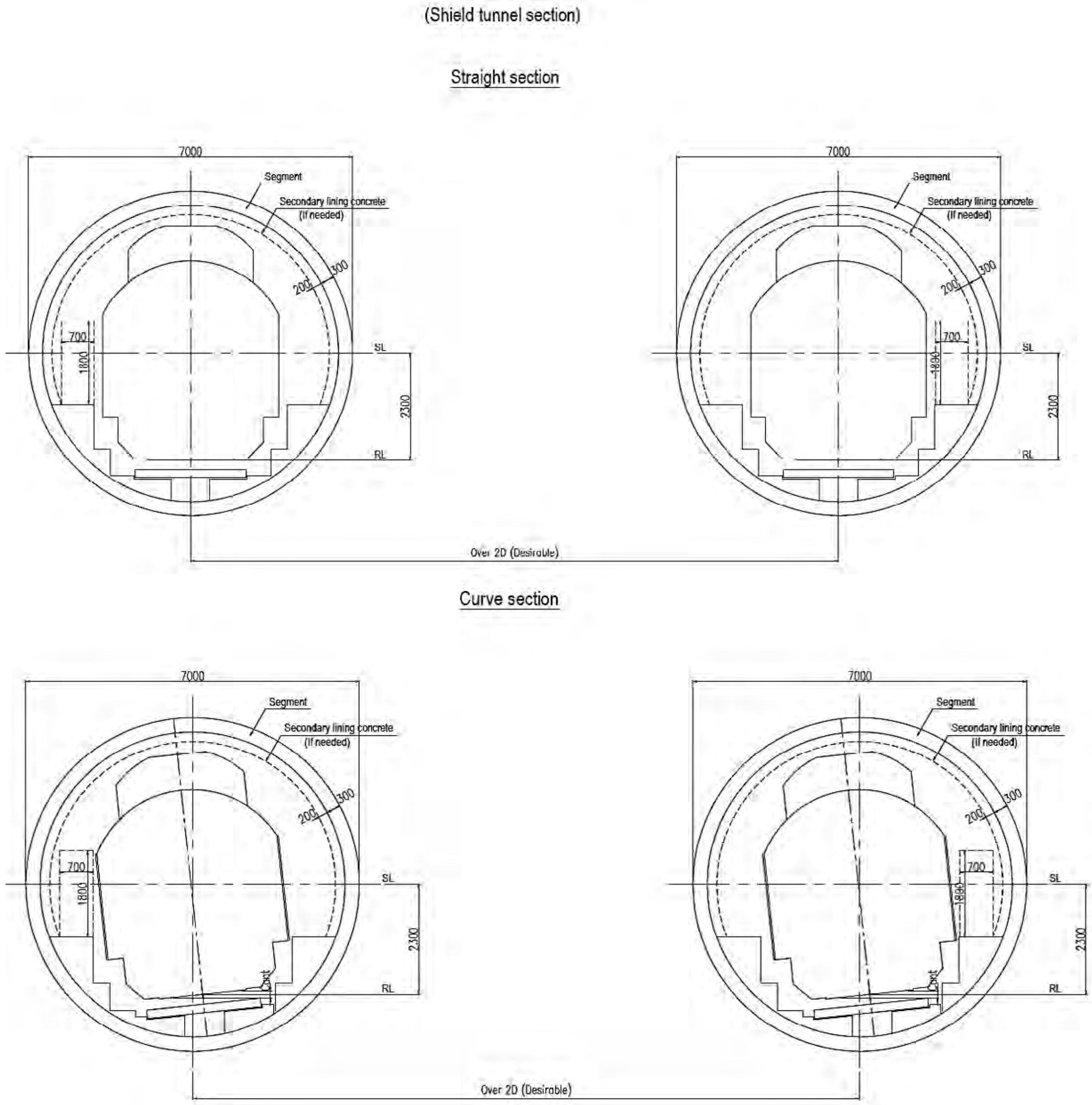


Source: JICA Study Team

Figure 3.4.11 Standard section diagram of cut and cover part (general part)

2) Shield Part

When designing a shield tunnel, the minimum required inner cross section must be set. When setting it, the following conditions need to be checked. Those are the clearance gauge, planar linear condition to consider the amount of expansion of the clearance gauge, track conditions such as cant and slack, space required for the installation of facilities required in tunnels (electricity, communication, signaling equipment, etc.), truck structure under RL, drainage facility, refuge space, construction margin, etc. For the railway shield in recent years, the secondary lining is generally omitted due to improvements in cutoff performance. However, it is thought that the space shall be secured as a reinforcement space for the future. Furthermore, regarding the segment, the RC segment is adopted as standard.



Source: JICA Study Team

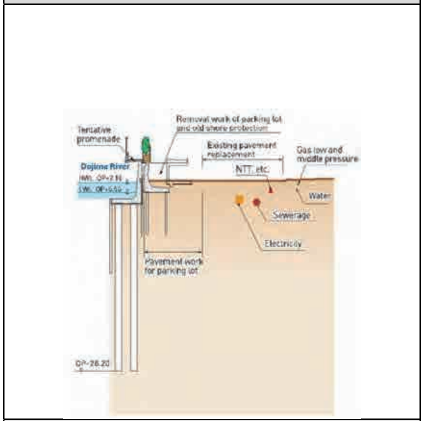
Figure 3.4.12 Standard section diagram of shield part

(3) Construction Method

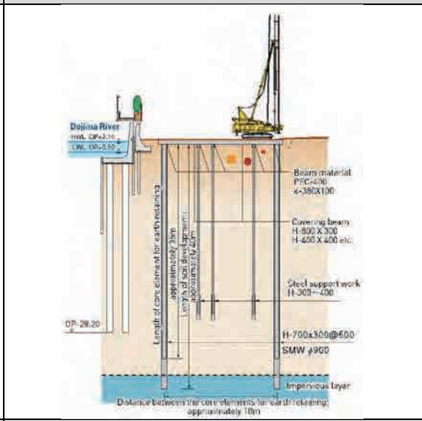
1) Cut and Cover Part

Examples of the construction method and construction procedure are shown in Figure 3.4.13. For the cut and cover method, the plans for temporary construction of the earth retaining wall and timbering work are important factors in the safety of construction, thus optimum plans must be prepared by taking into account the soil property conditions and marginal environment conditions.

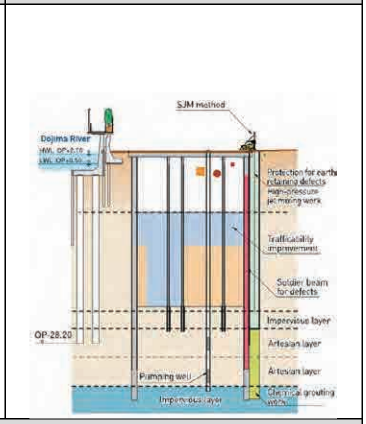
STEP 1 Preparation work



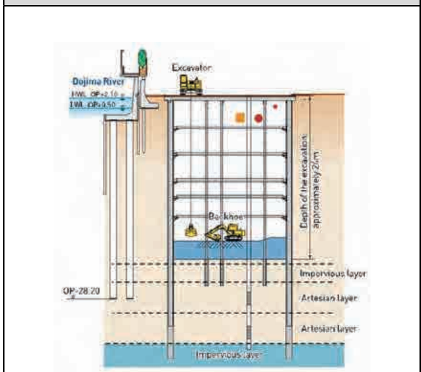
STEP 2 Earth retaining work, Surface lining



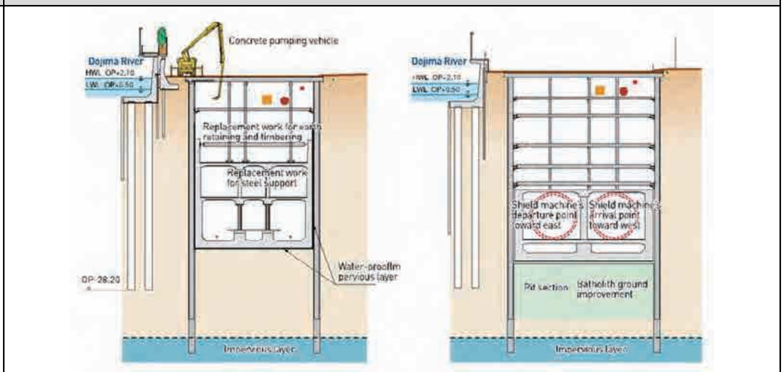
STEP 3 Ground improvement



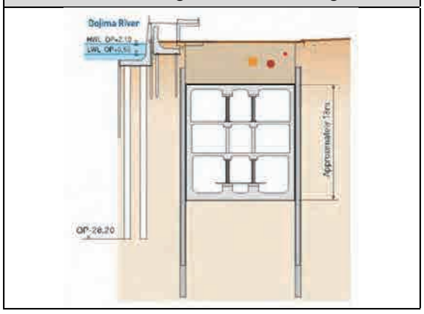
STEP 4
Excavation and installation of timbering for earth retaining



STEP 5
Station area work, Shield excavation, Railroad area work



STEP 6
Exits, Backfilling work, Restoring work



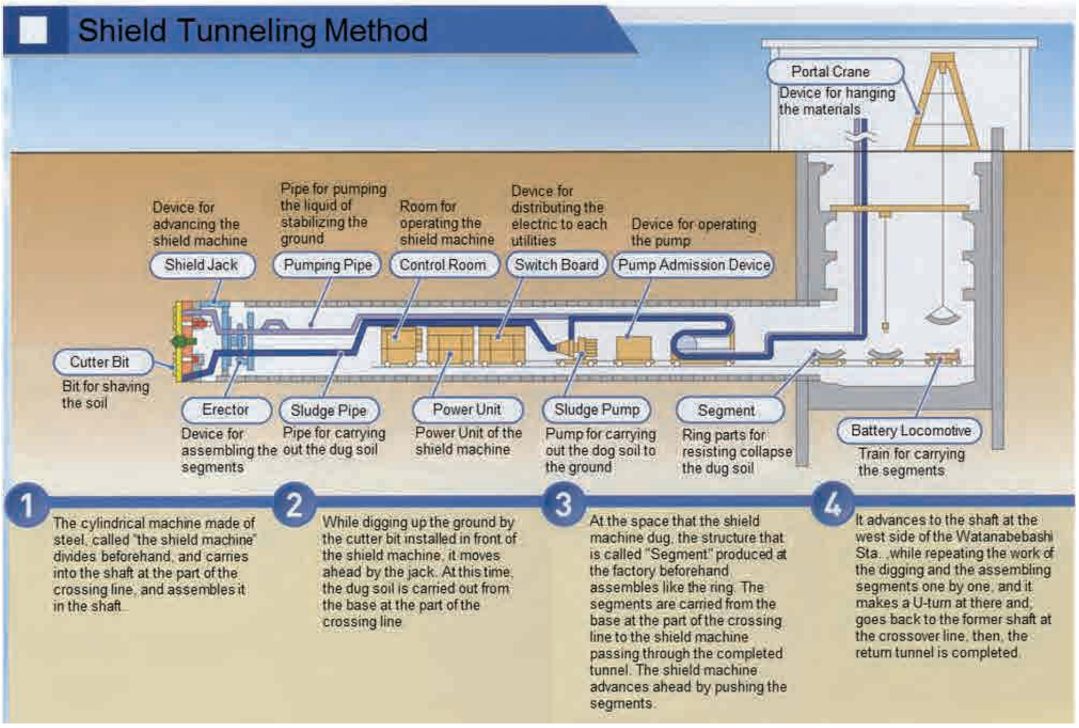
Source: Nakanoshima New Line: Technical Pamphlet

Figure 3.4.13 Example of the construction method and procedures of cut and cover part

2) Shield Part

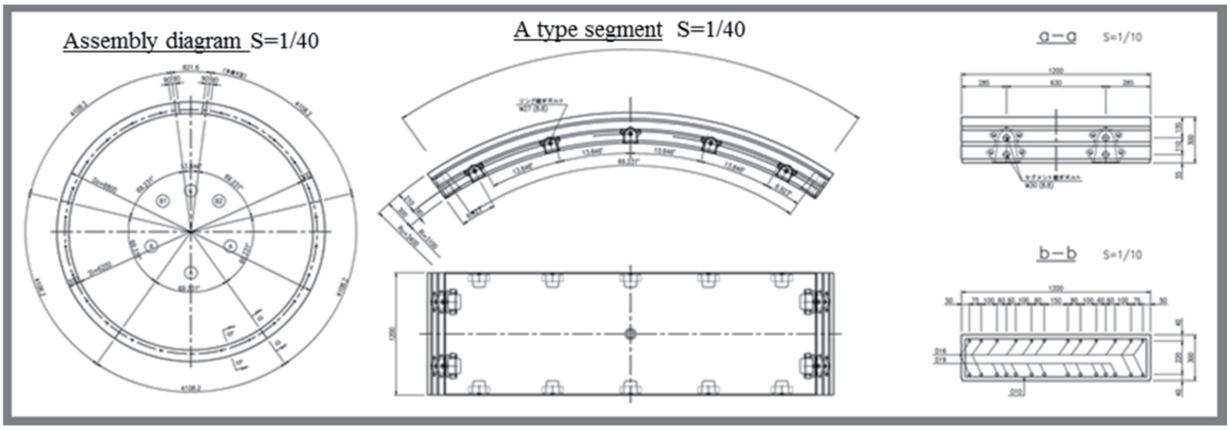
The parts between stations shall be constructed using the shield tunneling method as standard. A shield tunnel shall be a single-track, parallel shield tunnel. The number of shield machines to be manufactured shall be determined in consideration of a reduction in construction costs and construction processes. One example is as follows. After a shield machine completes one interval, the machine is pulled out and performs a U-turn construction, and then it performs the construction of another interval. The design and specification of the shield machine shall be determined by taking into account the soil property conditions and marginal environment conditions.

Figure 3.4.14 shows the construction method assuming the mud pressure shielding technique, and Figure 3.4.15 shows the outline of the segment.



Source: Nakanoshima New Line: Technical Pamphlet

Figure 3.4.14 Construction method of shield part



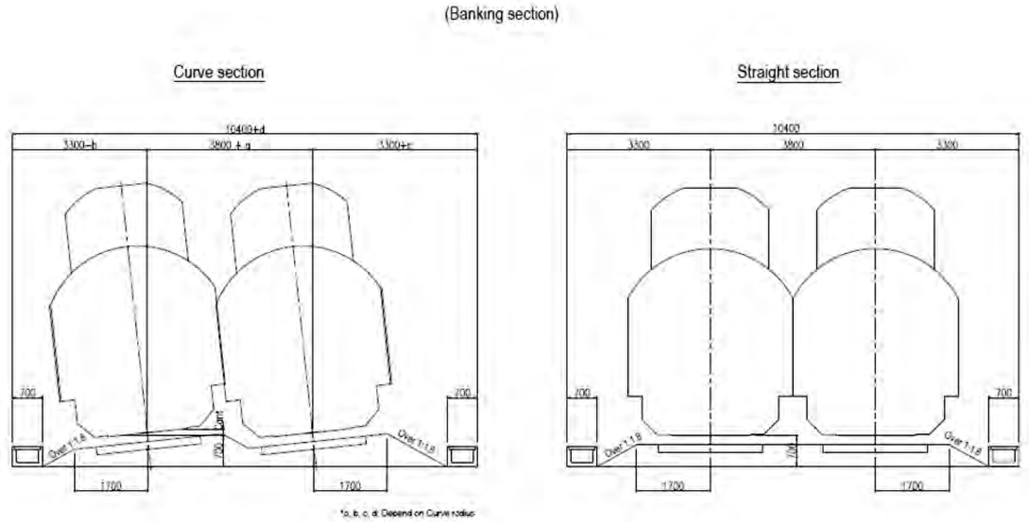
Source: Nakanoshima New Line: Technical Pamphlet

Figure 3.4.15 Outline of the segment

3.4.5 Outline design of suburban civil engineering facilities

(1) Outline

In the suburbs, rail tracks are laid down on an embankment in the median strip of the Thang Long road according to the plan in terms of the reduction in construction costs, and the standard section is as shown in Figure 3.4.16 (However, the VNR intersection part and bridge part shall have other structures). Although the relevant part is layered during the construction of the Thang Long road, compaction and consolidation of the soil are insufficient now. It seems that the settling of the Thang Long road today is substantial. Therefore, the construction method includes considerable ground reinforcement before laying down rail tracks to minimize settling. The plan also includes the introduction of a ballasted track structure that can accommodate a certain degree of settling.

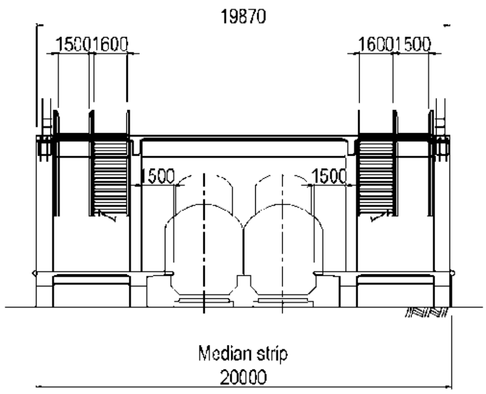


Source: JICA Study Team

Figure 3.4.16 Standard section diagram of suburban part

(2) Over-track station (two platforms with two tracks) *in the Thang Long road

In this plan, over-track stations (a ground station with a concourse floor above the rail track and platform) are planned as shown in Figure 3.4.17. The width is equal to the full width of the median strip, and opposite platforms are installed. When the effective width of a platform must be widened, it is possible to install stairs and escalators independently.

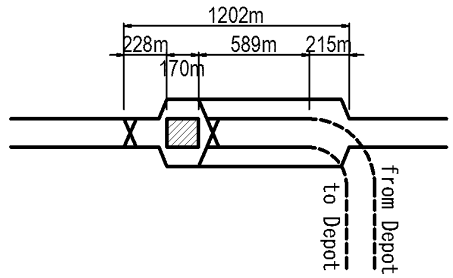
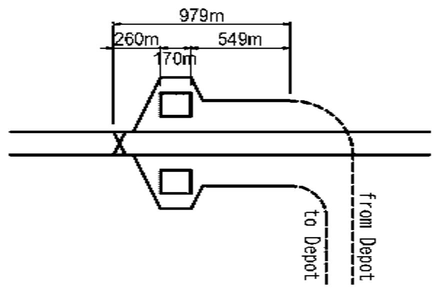
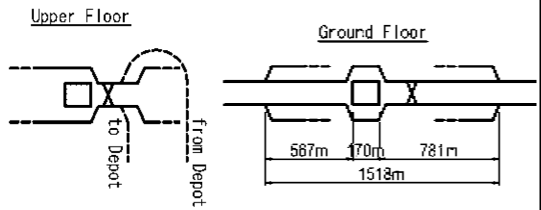


Source: JICA Study Team

Figure 3.4.17 Over-track station (two platforms with two tracks)

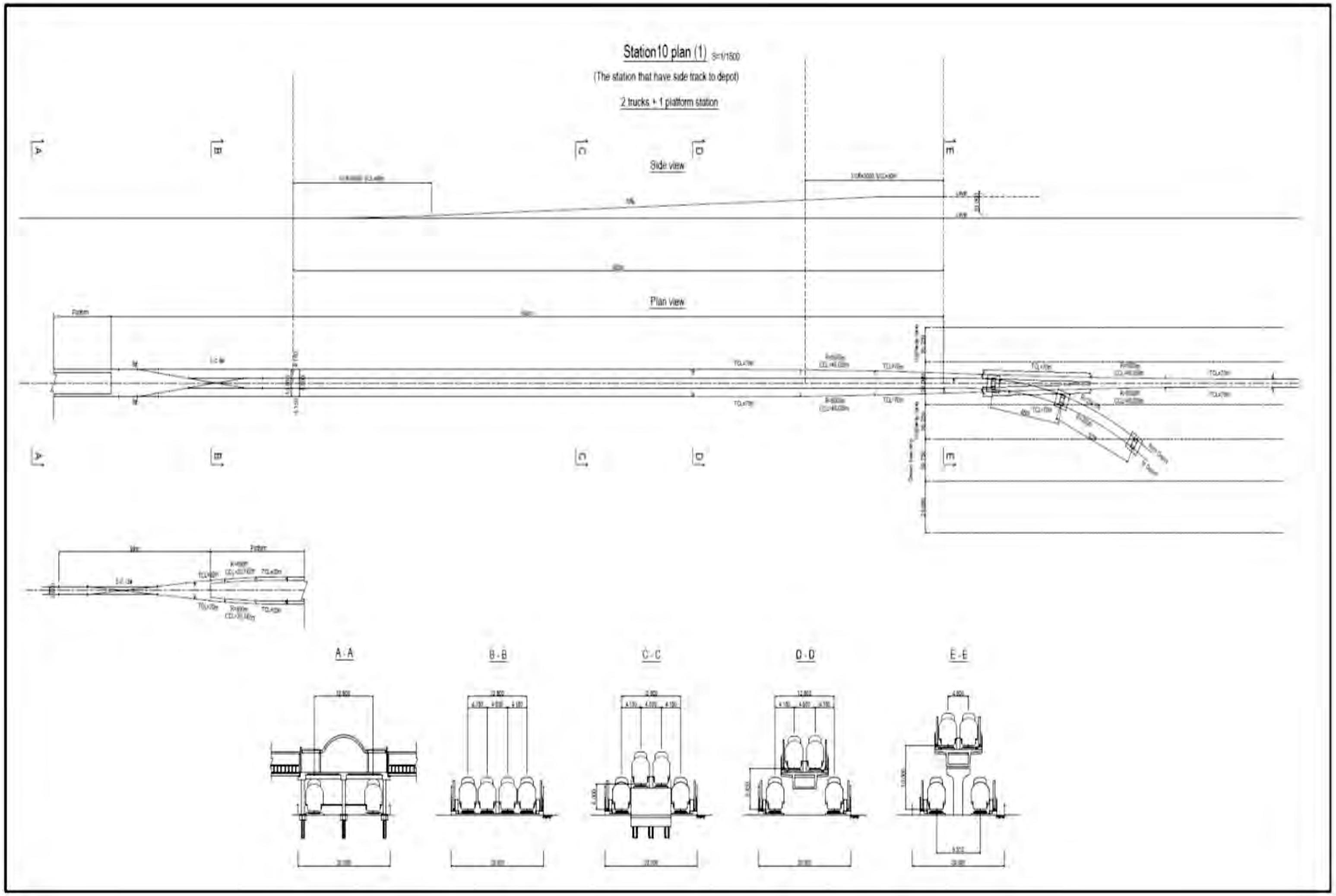
(3) Interconnection and Structure between St. 10 and Depot

For the connection of St. 10 and the depot, when the depot is located in an area away from the Thang Long road, a depot-in/depot-out track that runs above the road is required. Therefore, the depot-in/depot-out track must have an elevated structure, and several plans are conceivable as shown in Figure 3.4.18. Because the width of the median strip is 20 m and the structure is simple, it is judged that Plan A is appropriate. Figure 3.4.19 is a detailed drawing of Plan A.

	Plan A	Plan B	Plan C
schematic diagram			
Outline	Layout：1 platform with 2 tracks Required width: 20 m	Layout：2 platforms with 4 tracks (2 tracks in the middle are passing tracks) Required width: 29 m	Layout：2 platforms with 4 tracks (two-layer structure) Required width: 20 m
Problems	Trains from depot-in/depot-out tracks go derecly into the main line	The width does not fits within that of median strip (20 m)	- When transfering train going to the same direction, passengers needto go to the diefrent floor - East-bound depot-in/depot-out tracks have to go out once to the south of the Thang Long road - As having long straight lines, side tracks need the longest distance to come back to the main line - Structures are complicated
Evaluation	○(good) since the width fits within that of median strip	△ (relatively difficult) since the width does not fits within that of median strip	× (difficult) since there are so many problems

Source: JICA Study Team

Figure 3.4.18 Comparison of plans of elevated structure for the depot-in/depot-out tracks



Source: JICA Study Team

Figure 3.4.19 Outline of elevated structure of depot-in/depot-out tracks (Plan A)

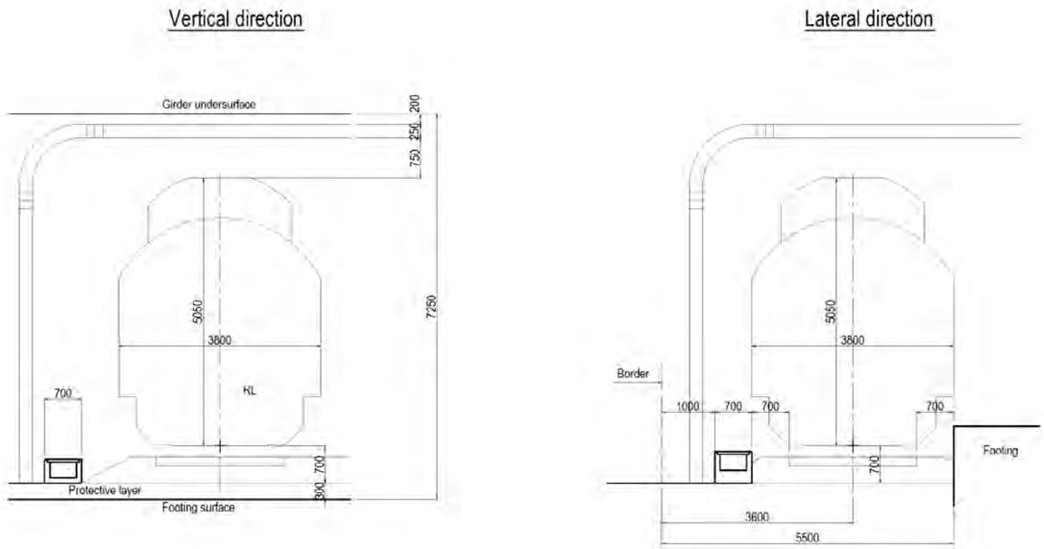
(4) Plan section of flyover part

As shown in Table 3.4.3, there were 10 crossing overpasses confirmed over the Thang Long road at the time of the survey. In this plan, the rail track is laid down on the median strip of the Thang Long road, and intersections with these overpasses are important for this plan. This is because project costs can be reduced if the line runs under the overpasses.

Here, Study Team examines the plan section as follows to lay down the rail track in this space and secure the power supply from the electric overhead line.

1) The clearance gauge shall be secured.
2) The overhead contact wire system shall be that of the electric overhead line when the design maximum speed is 130 km/h. (It shall also be suitable for the line for 160 km/h in the future.)
3) When the track FL is lower than the height of the Thang Long road, the drainage plan shall be considered.
4) Slope (roadbed) protection work shall be done completely.

The standard section of the flyover part is shown in Figure 3.4.20.



Source: JICA Study Team

Figure 3.4.20 Standard section of the flyover part

For the special parts with a height limit as described above, the plan shall be such that the longitudinal line shape at the flyover part is maintained as high as possible through the study to reconsider the clearance gauge of 5,050 mm as shown in Figure 3.4.20 and to shorten the pantograph on the car side. In addition, shown as Table 3.4.4, since flyovers at the points of 6km050m, 21km000m, and 32km100m are especially at lower point, plan shall be developed to secure the necessary height of overhead contact wire from the rail level.

Table 3.4.3 Outline of flyovers at the present time

Place	Height (m) from Footingsurface to Girder undersurface	Footing width (m)	Angle (Degree) Flyover and Road	Comments
6km050m	7.1	10.0	90	
7km800m	8.0	8.0	61	Footing and Road is parallel
9km800m	7.9	7.0	64	
12km600m	7.5	9.0	87	
16km150m	7.6	6.0	62	
20km050m	8.0	9.0	71	Footing and Road is parallel
21km000m	6.8	6.0	No Data	
22km700m	8.7	9.0	No Data	
28km200m	8.0	8.0	77	
32km100m	4.9	8.0	85	

Source: JICA Study Team

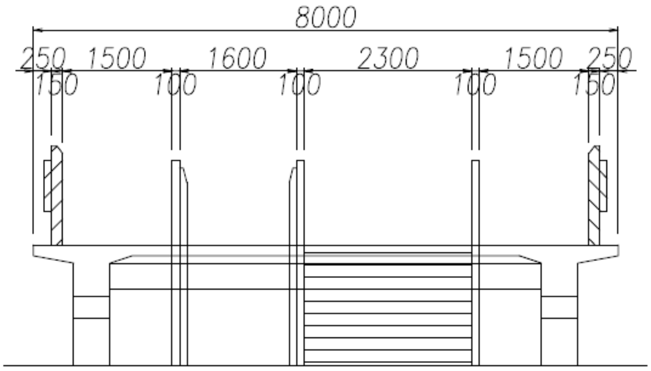
3.4.6 Outline of station facilities

(1) Facility plan

1) Platform standard section

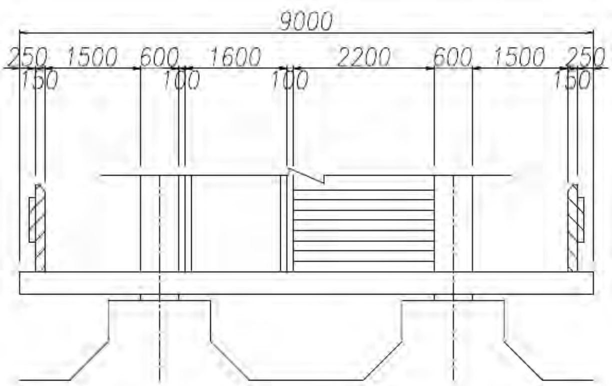
<Island Type>

When determining platform width, it may also be calculated from the demand forecast, but the physical condition at the stairs may be the determinant factor. In this study, it was determined by setting the effective width at the stairs as that of the stairs and the escalator and by adding the minimum passage width from the wall to the platform edge (platform fence) of 1,500 mm. The width of an elevated station is 8,000 mm and that of an underground station is 9,000 mm because there are columns.



Source: JICA Study Team

Figure 3.4.21 Standard section diagram of the platform at elevated part

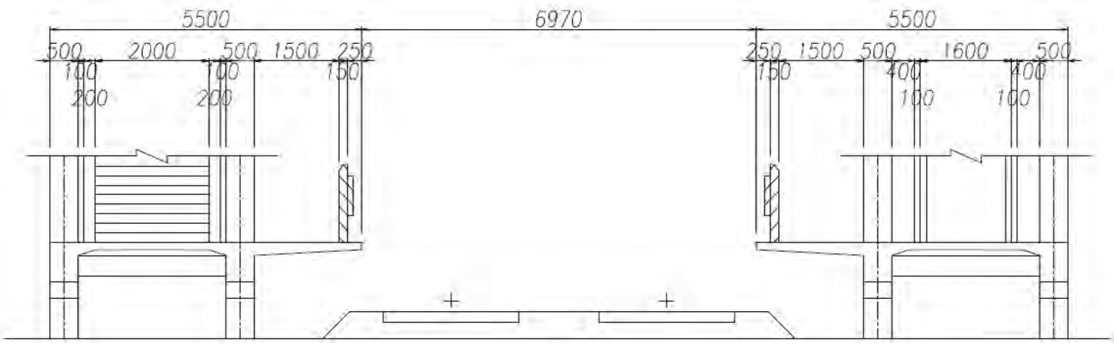


Source: JICA Study Team

Figure 3.4.22 Standard section diagram of the platform at underground part

<Opposite Type>

For opposite platforms, as in the island platform, the width was determined by adding the minimum passage width at the stairs of 1,500 mm.



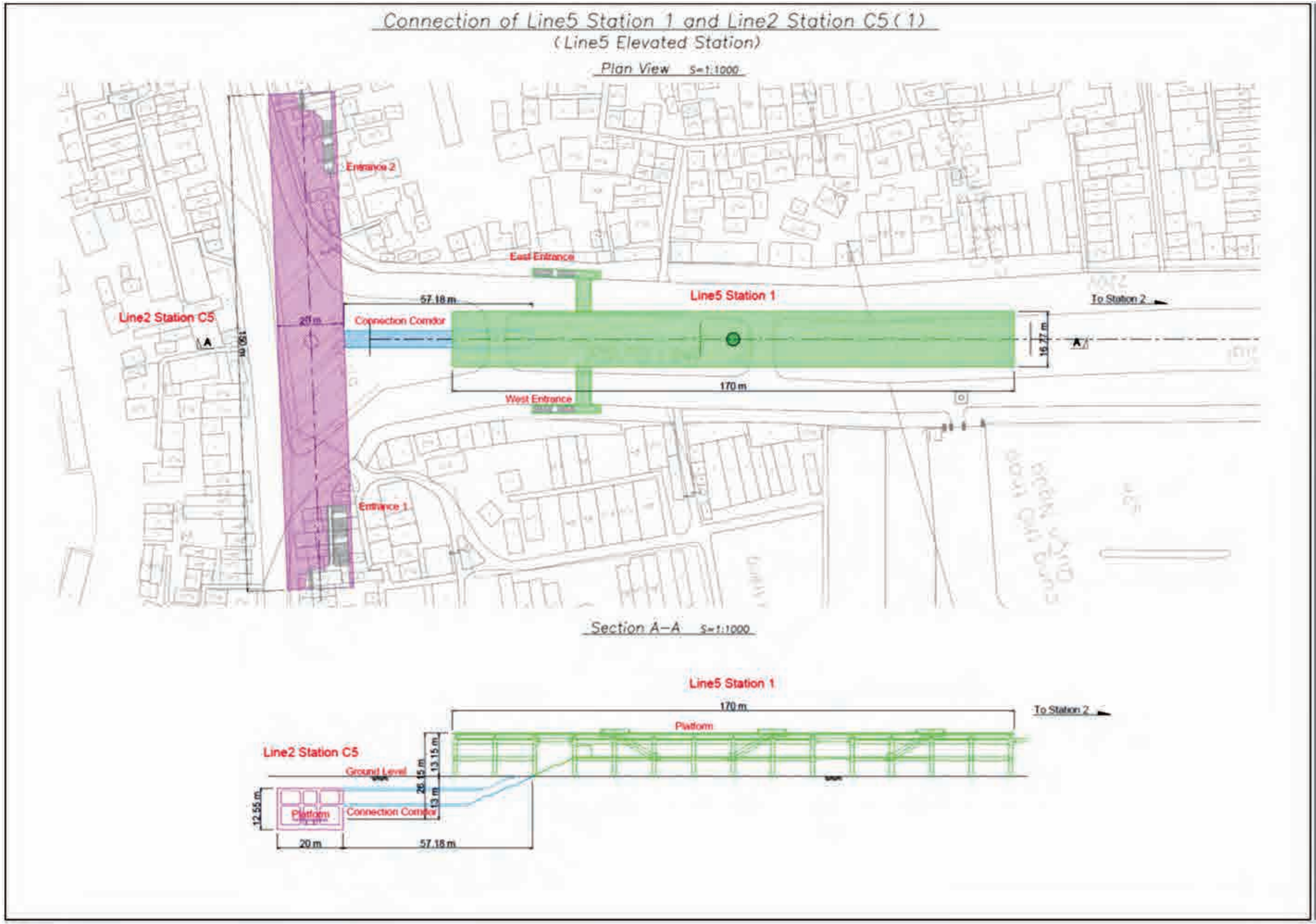
Source: JICA Study Team

Figure 3.4.23 Standard section diagram of the opposite platforms at above ground part

2) Transfer part to other lines (elevated and underground)

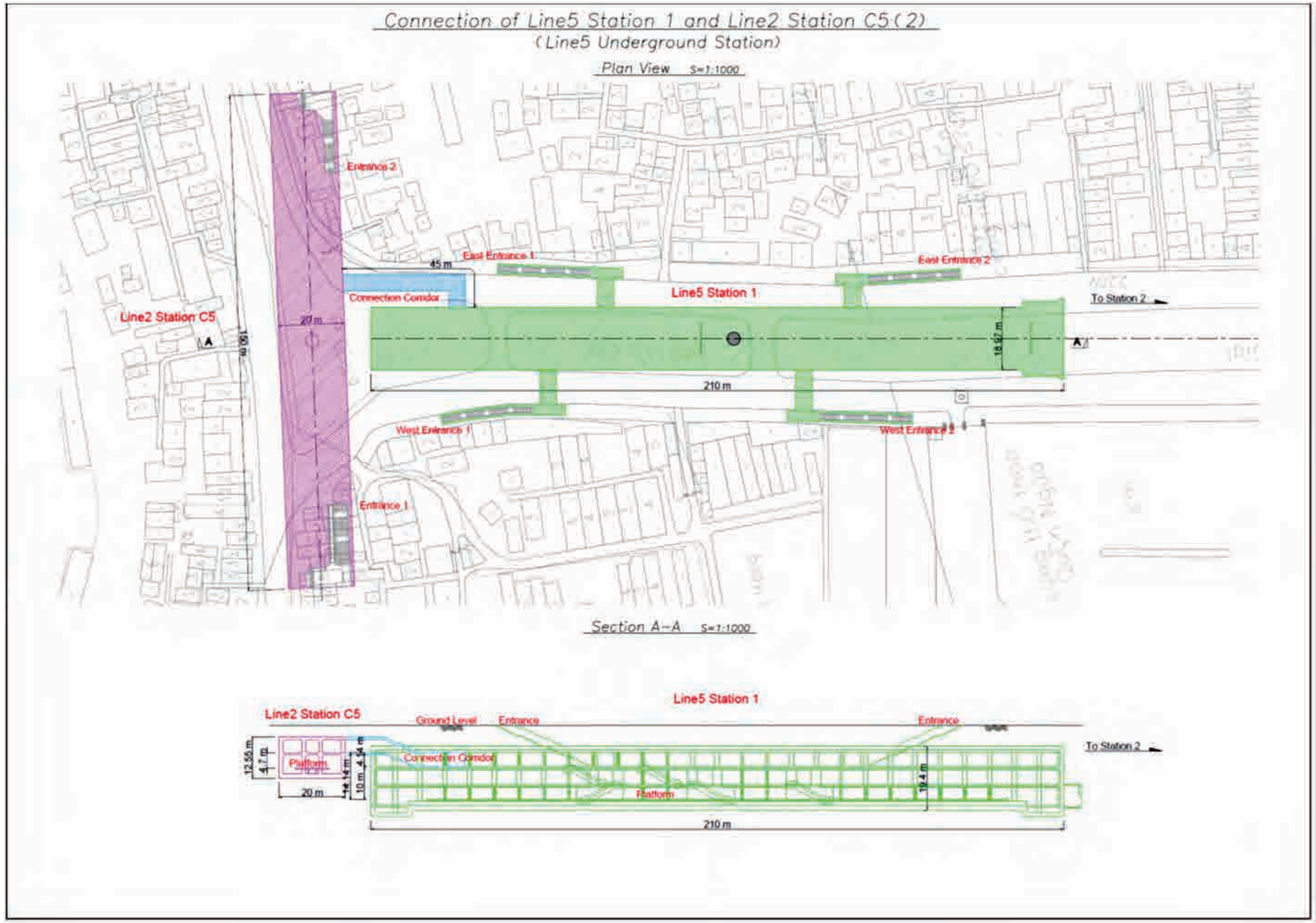
Transfers between this line and other lines are underway at St. 1 and St. 2. Therefore, St. 1 and St. 2 shall be studied on the transfer to Line 2 and Line 3, respectively. To ensure smooth movement at the transfer section, securement of sufficient width of passages and measures for the difference in levels by the stairs, as well as escalators, elevators, etc., are important. As a future plan, St. 4 will be connected to Line 4 and St. 5 will be connected to Line 8.

Here, the transfer routes at St. 1 to Line 2 under consideration in the cases of an elevated and an underground station are shown in Figures 3.4.24 and 3.4.25, respectively. Also, the transfer routes at St. 2 to Line 3 in the cases of an elevated and an underground station are shown in Figures 3.4.26 and 3.4.27, respectively.



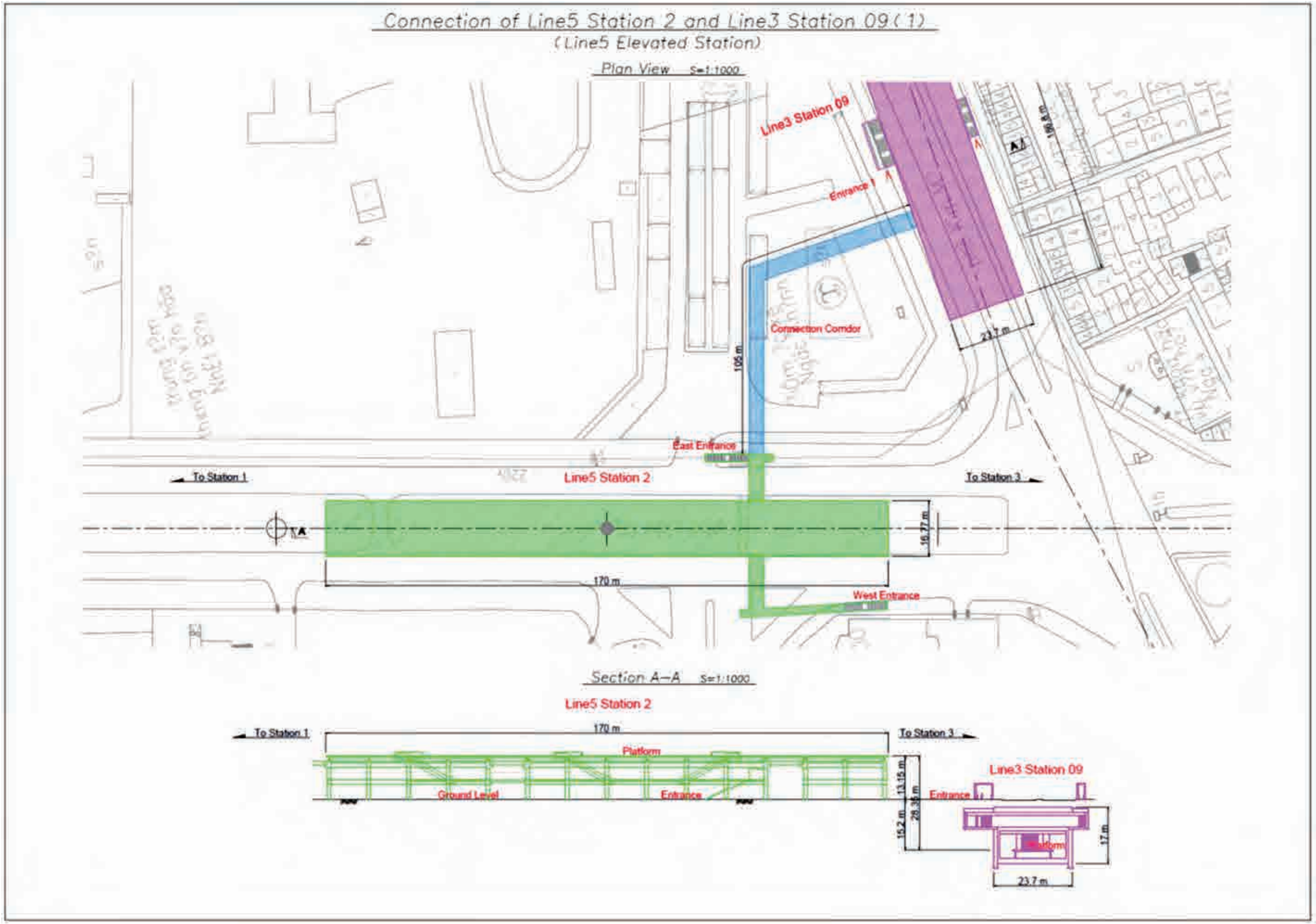
Source: JICA Study Team

Figures 3.4.24 Connection between St. 1 of Line 5 and St. C5 of Line 2 (elevated)



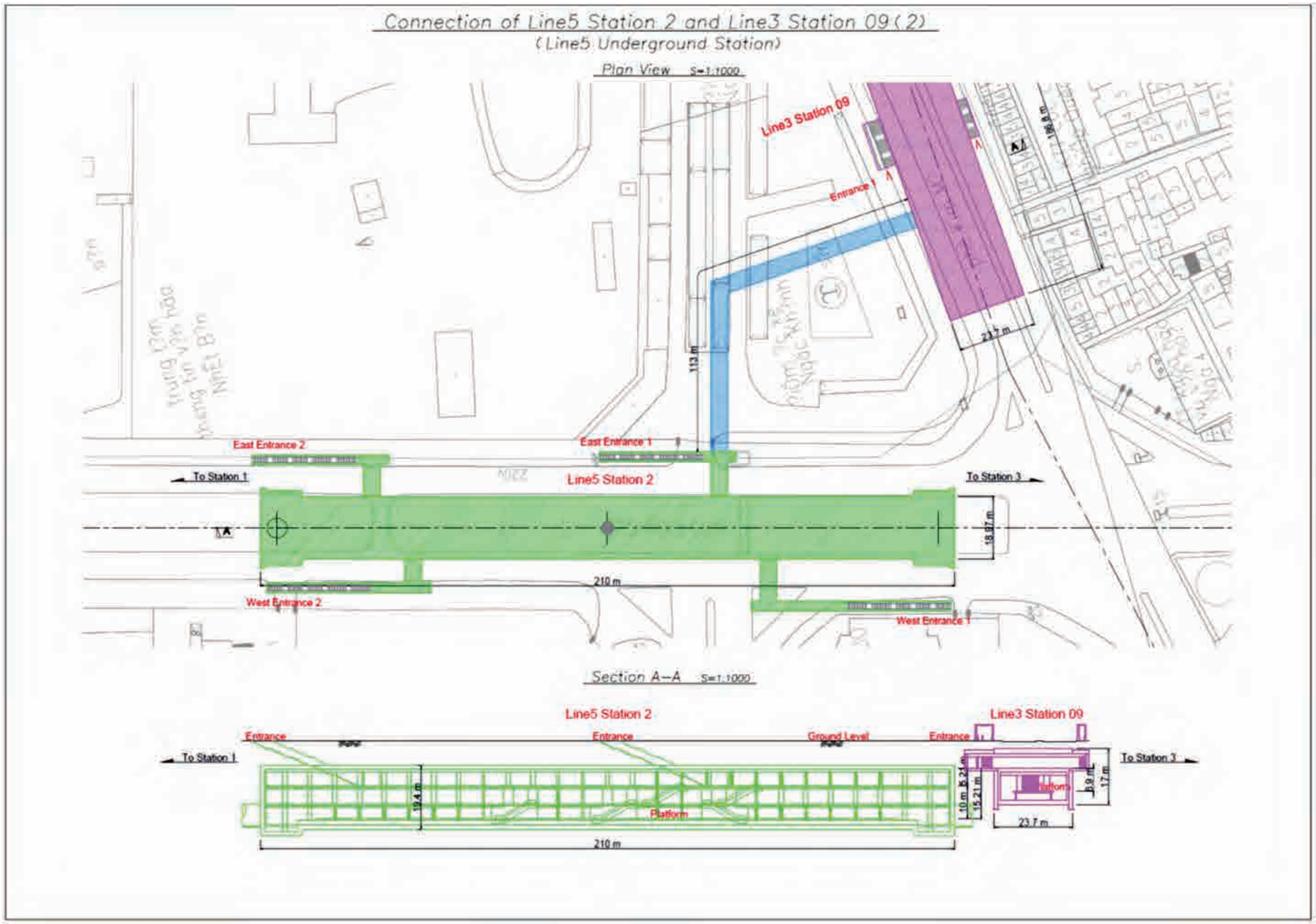
Source: JICA Study Team

Figures 3.4.25 Connection between St. 1 of Line 5 and St. C5 of Line 2 (underground)



Source: JICA Study Team

Figures 3.4.26 Connection between St. 2 of Line 5 and St. 09 of Line 3 (elevated)



Source: JICA Study Team

Figure 3.4.27 Connection between St. 2 of Line 5 and St. 09 of Line 3 (underground)

(2) Station facilities

1) Electric facility plan

The following facilities shall be introduced to the stations to provide passenger with safety, smooth movement and guidance, and comfortable space at the station.

(i) Elevator and escalator facilities

Escalators and elevators shall be installed in order to improve the convenience and safety of movement for people who are elderly, pregnant, or disabled. Energy saving shall be achieved by introducing automatic operation and unmanned very low speed operation functions.

(ii) Water supply and drainage facilities

The facilities that supply water and hot water required in the station and process the sewage, wastewater, rainwater, drainage water, or excess water shall be introduced.

(iii) Air-conditioning facilities

The facilities shall be installed for the comfort of the waiting rooms on the platforms of a ground/elevated station and the station offices and for the protection of electric facilities and devices in the signaling equipment room, communication device room, and electric room.

(iv) Power receiving and transformation facilities

The facilities that supply power to the station electric facilities and signal/communication facilities shall be installed in the electric room of each station.

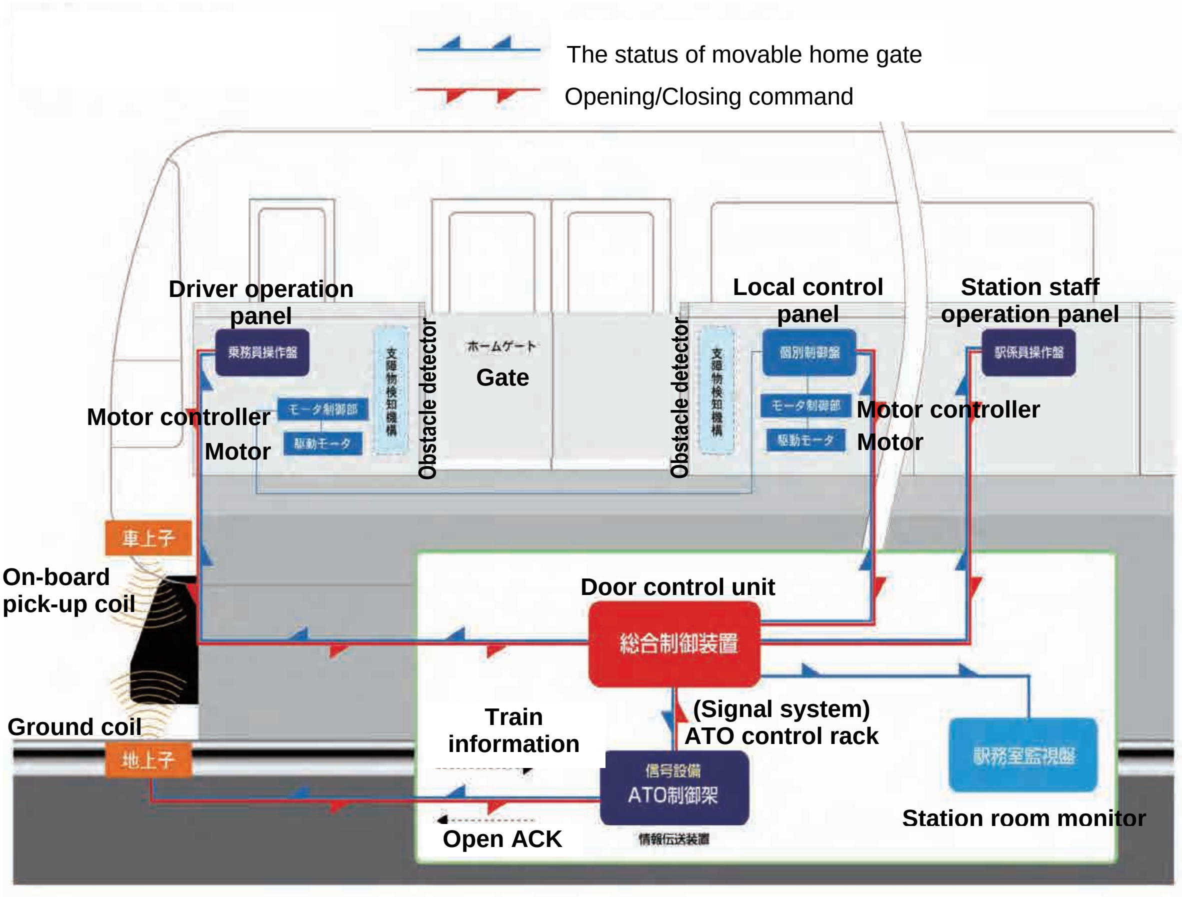
(v) Lighting facilities

LED lighting with low power consumption and long life shall be used as standard. Products of a straight shape, bulb shape, etc., shall be adopted depending on the application, purpose, and architectural design.

(vi) Platform screen door (PSD) (refer to Figure 3.4.28)

With the purposes of preventing passengers falling from the platform, contact accidents with cars, door pinching accidents, etc., the introduction of platform screen door shall be studied. Effects such as promotion of a barrier-free platform, securement of railway operation punctuality, securement of safety of operation without conductors on board in the future, etc., can be expected.

The operation of the PSD is controlled through communication between the car and platform after the train stops at the platform. The open/close state of the home gates can be grasped on the monitoring/operating panel for train drivers, station staff, and in the station service room.



Source: JICA Study Team

Figure 3.4.28 Composition diagram of PSD system (example)

2) Station facilities plan

The following facilities that are required for the spaces used by passengers, station staff, and technical staff shall be mainly adopted.

(i) Station service room

The staff in this room guide people using the station and respond to various inquiries.

(ii) Electric/signaling facilities room

To supply low voltage to station facilities and railway electric facilities, electric power at a high voltage of 6,600 V is stepped down to a low voltage of 220 V or 380 V, and then the low voltage is distributed to various facilities for electricity, electric power, signals, communication, etc. The devices are also installed.

(iii) Disaster prevention management room

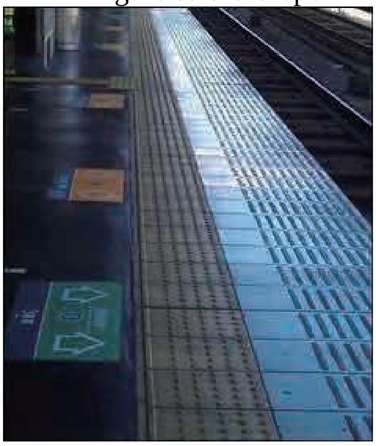
For an underground station, this is a room where personnel usually collect information, communicate messages and instructions, broadcast guidance to passengers, and monitor and control the fire shutters.

(iv) Other facilities

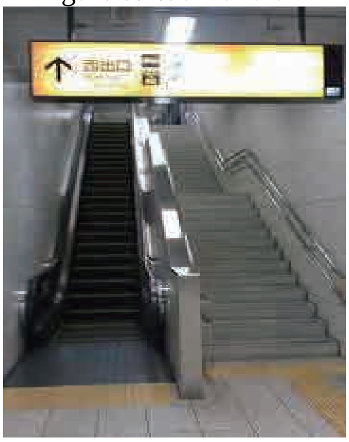
Waiting rooms, toilets, and signs within a station shall be installed. For major stations, the facilities for station staff and train drivers shall be installed (e.g. meeting rooms, rest stations, nap rooms, bathrooms, etc.).

Source: JICA Study Team
Figure 3.4.29 Slope

Source: JICA Study Team
Figure 3.4.30 Handrail



Source: JICA Study Team
Figure 3.4.31 Braille blocks on the platforn



Source: JICA Study Team
Figure 3.4.32 Escalator

Source: JICA Study Team
Figure 3.4.33 Elevator

Source: JICA Study Team
Figure 3.4.34 Multifunctional toilet

3) Facilities for underground station

(i) Ventilation and smoke control facilities

Facilities shall be adopted that can ventilate smoke effectively from stations and between stations. A smoke control facility can be combined with a mechanical ventilation facility. The smoke control facilities must be equipped with an emergency power source. However, ventilation facilities need not be installed when sufficient natural ventilation can be obtained.

(ii) Power feeding and distributing facilities

The electric facilities for an underground station shall be fed according to the priorities of the electric applications.

1st load: The facility is fed by double systems at the same time to prevent electric problems, power failures, etc. This includes emergency lighting, automatic fire extinguishing facilities, fire protection facilities, evacuation guidance facilities, ventilation/smoke control facilities, broadcasting facilities, signal/communication facilities, cutoff iron door, drainage pump, etc.

2nd load: The facility is fed by one power source or by two wiring systems from two power sources. This includes lighting of ground platform, elevators, sewage drainage pump, station office facilities, etc.

3rd load: The facility is fed only by one power source or two power sources, and the power to this facility can be stopped when the power sources are to be worked on. This includes cooler facilities, bathroom water supply facilities, lighting for advertisement, etc.

(iii) Emergency lighting facilities and standby power source

These facilities are important to evacuate and guide railway users from the building in case of a power failure. A battery system shall be installed that switches to a standby power source automatically when the normal power source is cut off and has a capacity to continually light up the lighting facilities for 30 minutes.

(iv) Emergency power generating facilities

When a power failure due to the power company occurs, this facility shall be activated automatically and start transmission of electricity within 40 seconds. A gas turbine power generating facility shall be installed to supply power to the important electric facilities in the station. The electric load to which the facility can fed electricity is limited, and the facility stops automatically when the power comes back.

(v) Cooling facilities

For a zone of an underground station with many passengers getting on and off where temperature is high, a cooling facility shall be installed.

(vi) Water supply and drainage facilities

The following items shall be considered for water supply facilities for an underground station:

(a) For an underground station, two independent water supply facilities for domestic use water for passengers and staff and for fire prevention use shall be installed.

(b) The amount of water supply shall be based on time and location to supply the required amount for every application.

(c) The water source shall be tap water from the city, and the water supply facility shall have a water storage tank in an underground facility. Water shall be supplied to the required faucet from the tank using a pump.

(vii) Sewage drainage facilities

The drainage facility for domestic use water in the station (bathrooms and toilets) and leaked water from tunnels shall be installed, and drainage pumps shall be installed at the required locations in tunnels between stations, and at the station.

(viii) Firefighting facilities (refer to Figure 3.4.36)

Fire alarm facilities, emergency announcement facilities, and emergency lighting facilities shall be introduced. For a large station, a complex monitoring board that controls disaster prevention facilities, lighting, elevators, air-conditioning systems, other devices, and facilities in an integrated fashion in the station service room to integrate monitoring and control functions.

(ix) Measures for fire

The following measures shall be taken:

(a) As a general rule, fireproof materials shall be adopted for structures in an underground station to prevent fire. Additionally, the cables shall be fire-retardant and shall not produce halogen gas when burned.

(b) In a station, a disaster prevention management room shall be installed where personnel usually collect information, communicate messages and instructions, broadcast the guidance to passengers, and monitor and control fire shutters etc.

(c) In a station, alarm facilities (including fire alarm facilities), communicator, evacuation guidance facilities (including securement of at least two different evacuation routes, emergency lighting facilities), fire-retarding doors, etc., shall be installed.

(d) In an underground station, fire extinguishing facilities such as fire extinguishers, indoor fire hydrants, sprinklers, connected water lines for firefighting teams shall be installed as necessary.

(x) Measures for immersion and waterproof

For an underground structure, mound-ups and water sealing plates shall be installed at the entrances and exits to prevent water from flowing into the underground space from roads. The water sealing plates are required to respond to floods due to sudden heavy rains. Maintenance and training shall be performed on a routine basis for an emergency. Openings such as ventilating openings shall be installed at a height free of water immersion.

Source: JICA Study Team

Figure 3.4.35 Example of water sealing plates

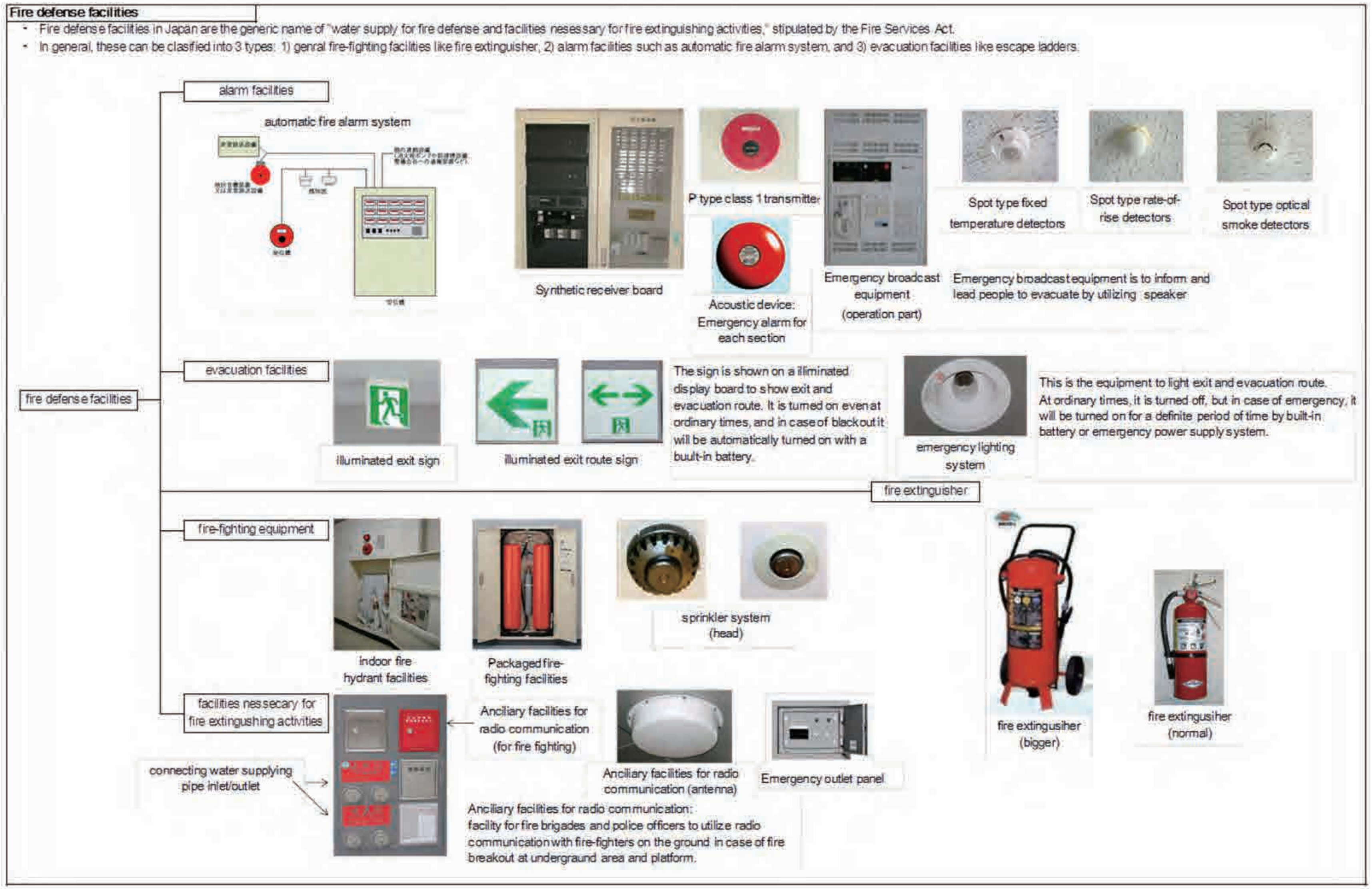


Figure 3.4.36 Fire-fighting facilities

Source: JICA Study Team

(3) Station layout

The layout of stations shall be easy-to-understand for people using the station and be easy for station staff to guide people. For this purpose, ticket gates are located at only one location and the station concourse is as small as possible. Therefore, the space for improved convenience of station users and the spaces where commercial facilities can be located in the future are also secured. For the plan in which elevated stations are used in the midtown, the spaces that can be used as bike parking lots, commercial facilities, and the facilities for the convenience of passengers are secured just under the station as an efficient use of areas under the elevated station.

The general drawings of a whole station including the layout for (i) elevated stations in the midtown area, (ii) underground stations in the midtown area, and (iii) ground stations in the suburban area are as follows:

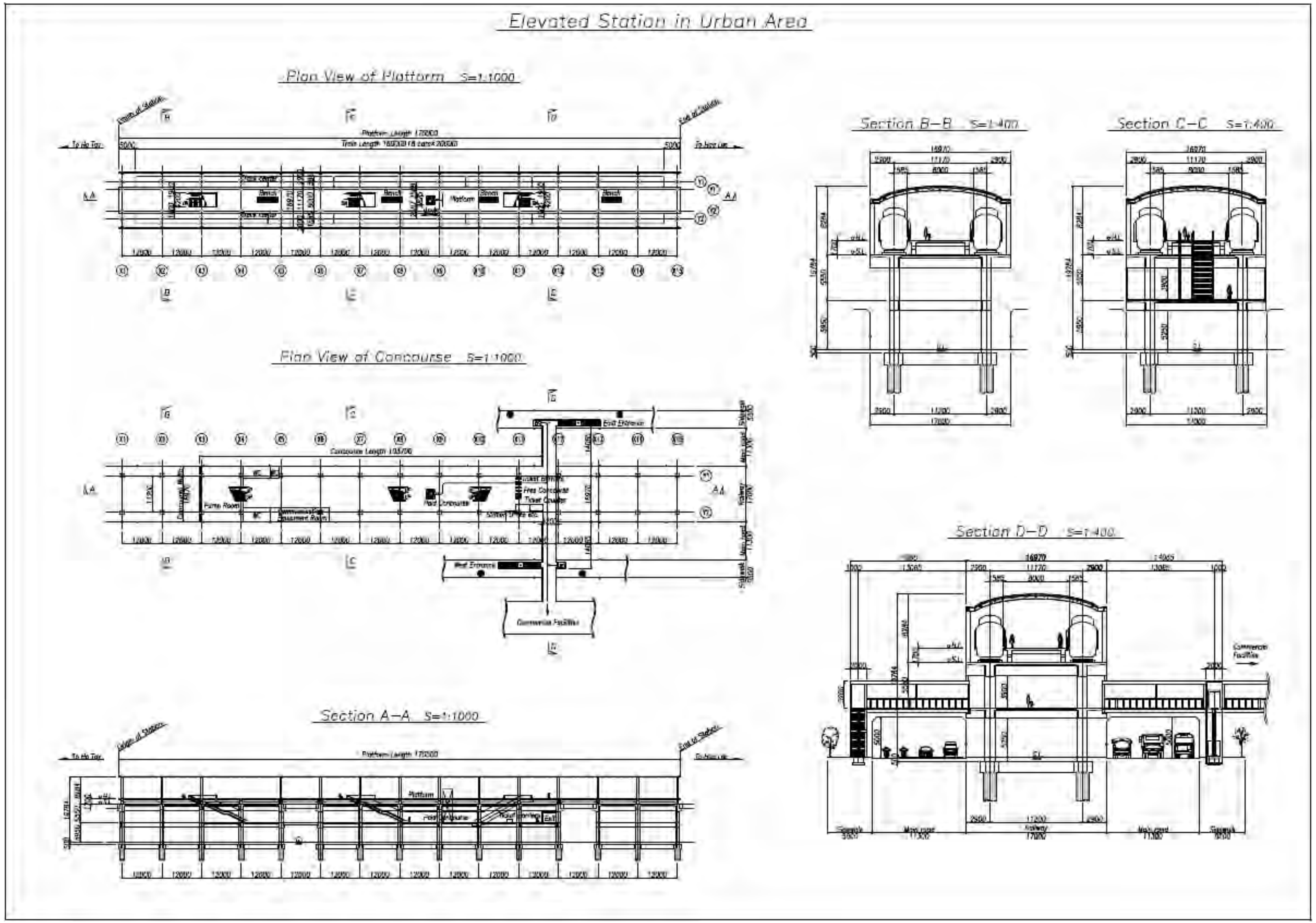


Figure 3.4.37 Elevated station in urban area Source: JICA Study Team

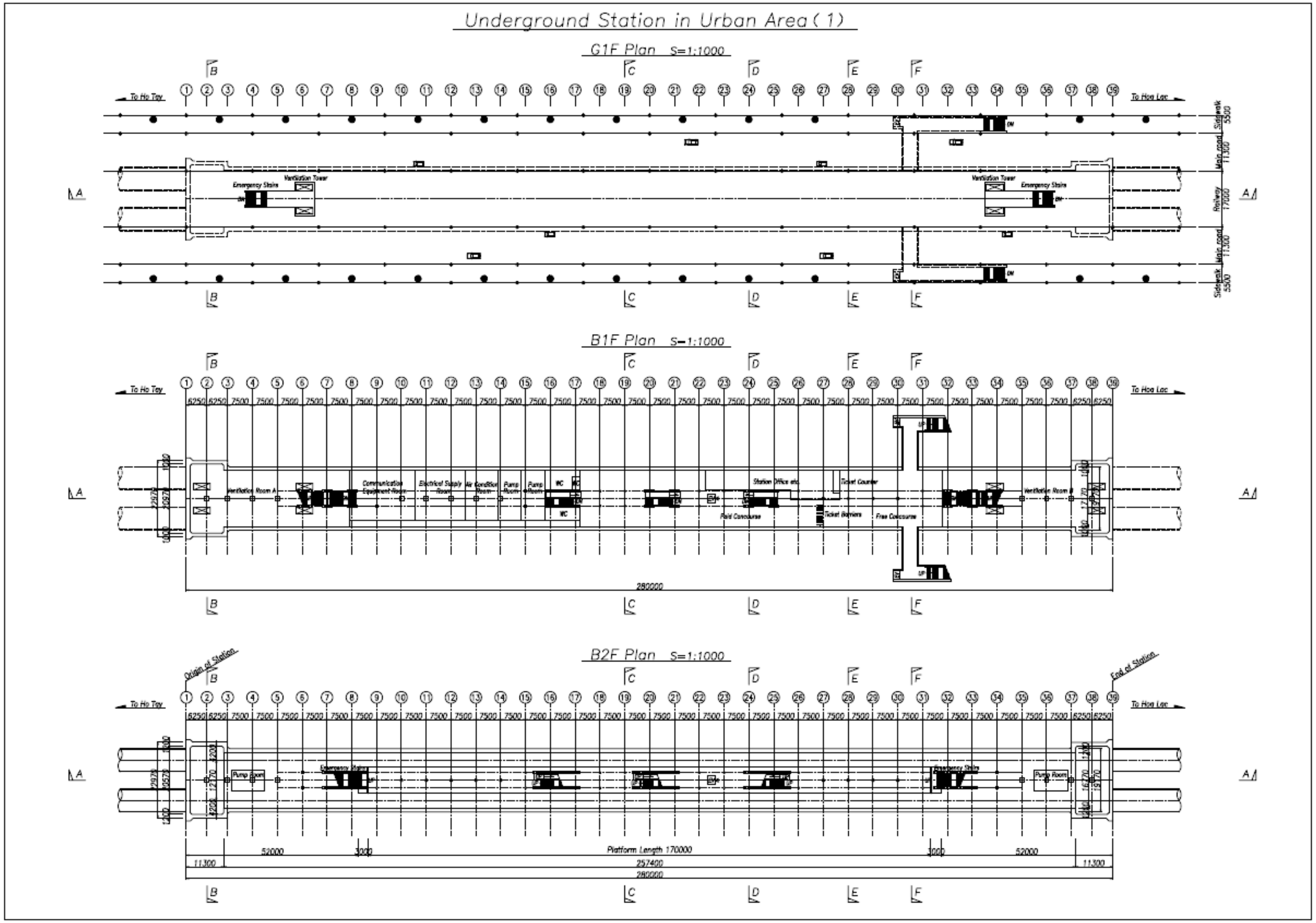


Figure 3.4.38 Underground station in urban area (1) Source: JICA Study Team

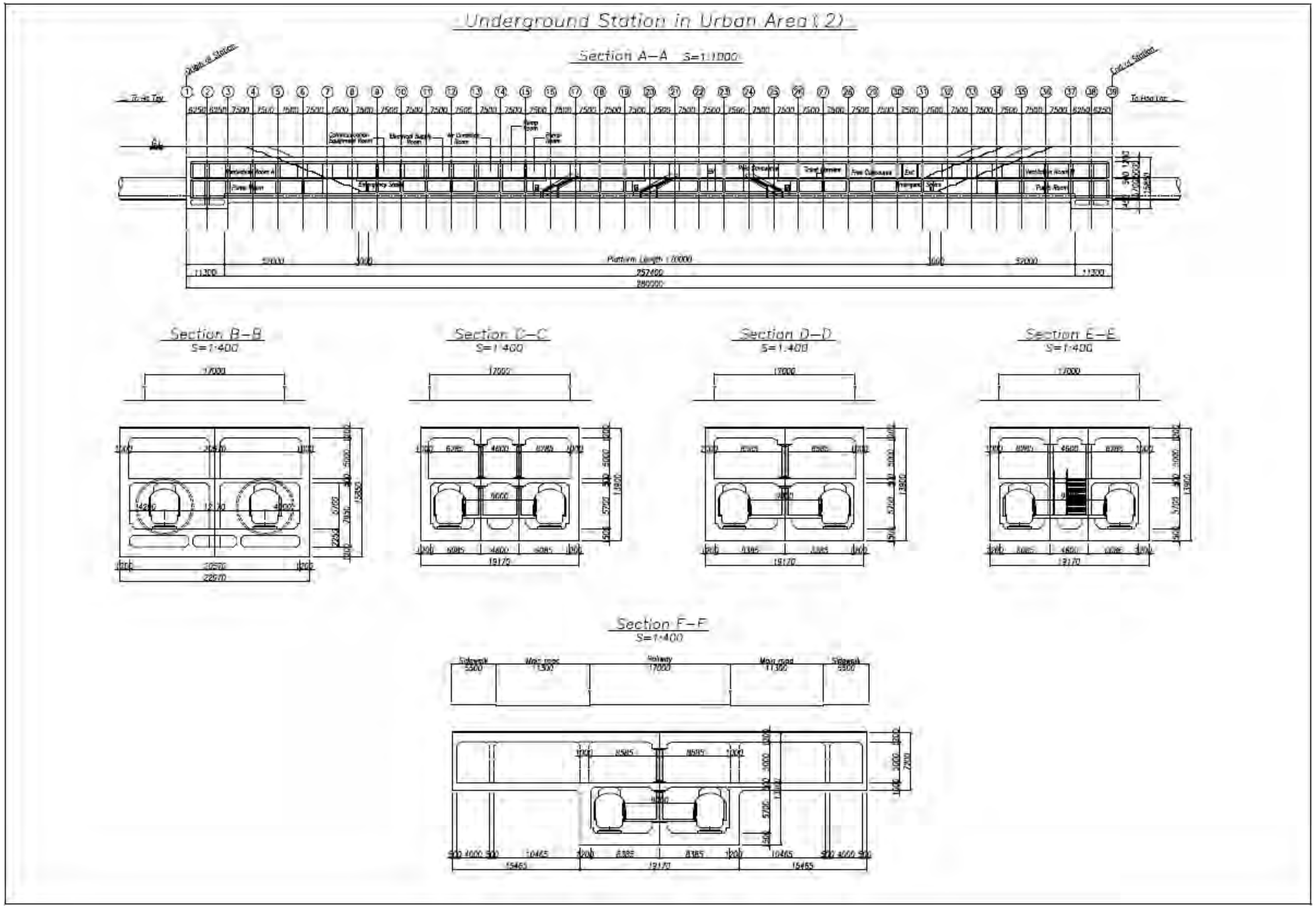


Figure 3.4.39 Underground station in urban area (2) Source: JICA Study Team

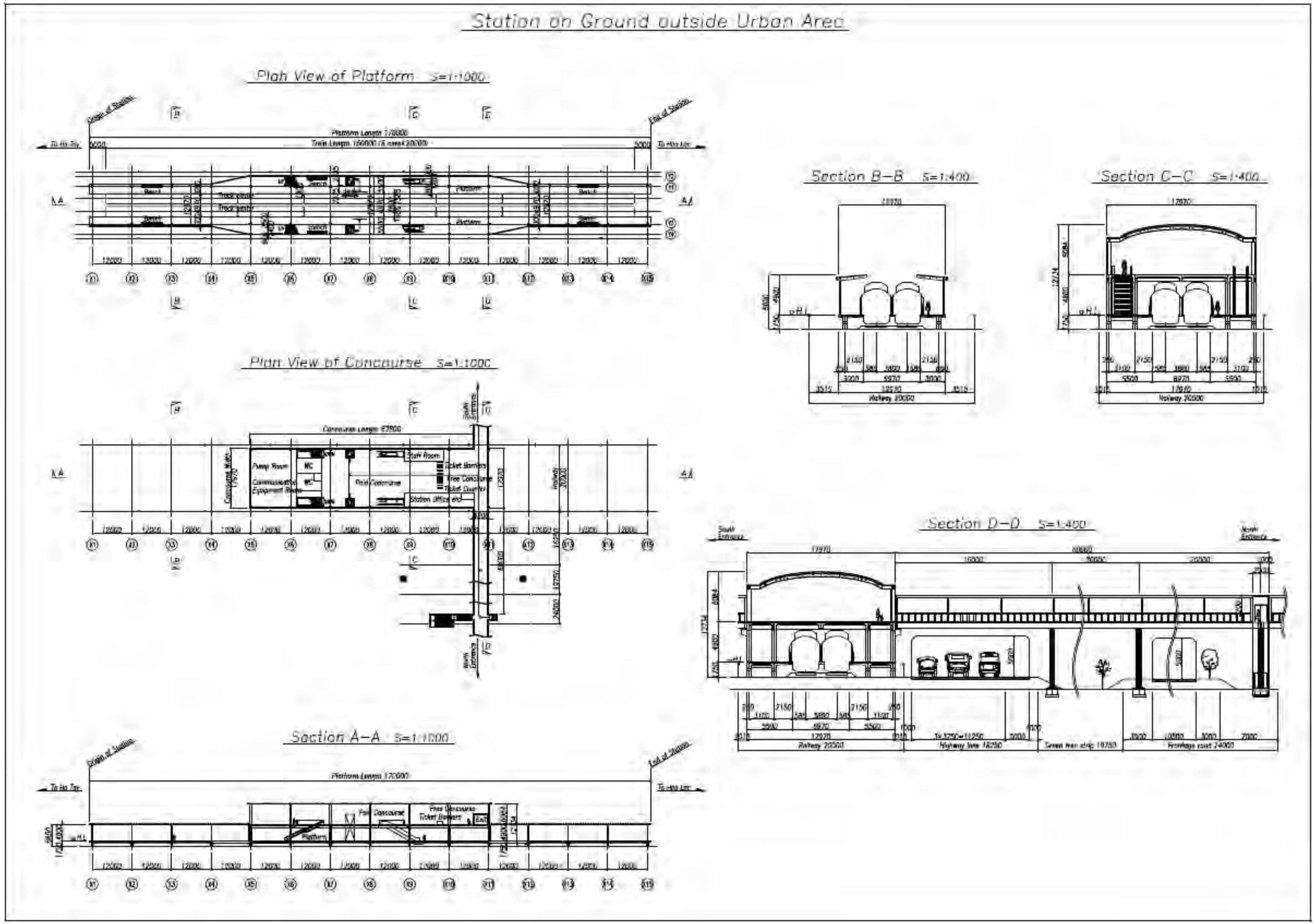


Figure 3.4.40 Ground station in suburban area Source: JICA Study Team

3.4.7 Technical Issue

(1) Alignment and structure near the Ring Road 2

Improvement of the Ring Road 2 is scheduled between St. 3 and St. 4. In this plan, in addition to a road plan that crosses this line, Nguyen Thanh Street, on which this line is planned, is scheduled to be elevated, and construction has already started.

Basically, the study here shall realize both the road and railway structures. Table 3.4.4 shows the alternative plans for cases where the structure in the midtown area is elevated or underground. When the structure in the midtown area is elevated, although the construction location of the abutments of railway structures shall be studied further, Plan B is desirable because the foundation piles of the existing road bridges over a river are obstacles. When the structure in the midtown area is underground, although the existing road bridges over a river need to be rebuilt, Plans E and F are desirable. In the discussion with the administrator in Vietnam, the opinion is that Plan D is desirable. However, there is concern about vibration affecting the surrounding buildings, thus Plans E and F were prioritized in this study.

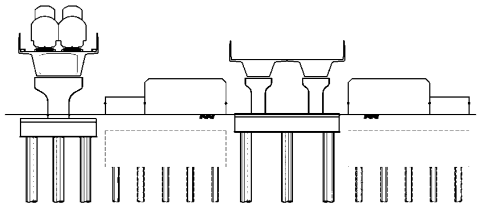
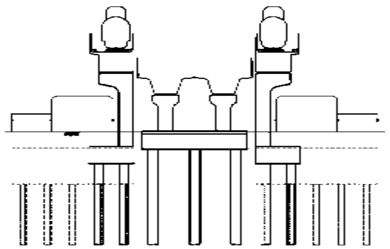
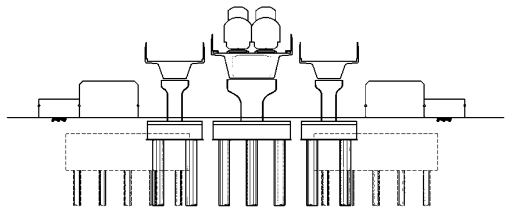
(2) Alignment near the Ring Road 3

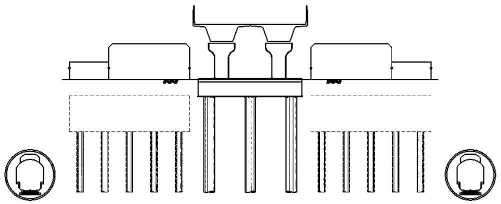
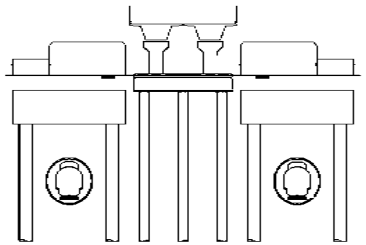
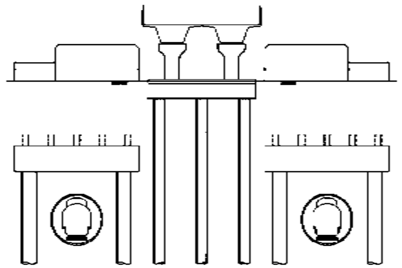
When the structure in the midtown area is underground, an alignment that runs between piers shall be planned at the intersection with the Ring Road 3. Therefore, although the alternative plans as shown in Table 3.4.6 were compared and studied, it is thought that Plan A is appropriate in terms of the securement of maximum design speed.

(3) Horizontal alignment of the 1km500m point

With regard to the current situation of the road between St.2 and St.3, median strip is too narrow and curved section can be seen. Moreover, there is a pond in this vicinity and it is surrounded by residential area. In case of constructing the elevated structure, therefore, those situations need to be considered when railway alignment shall be planned. Table 3.4.6 shows several plans of the horizontal alignment in this section, and this study recommends Plan B in which resettlement does not need to be implemented.

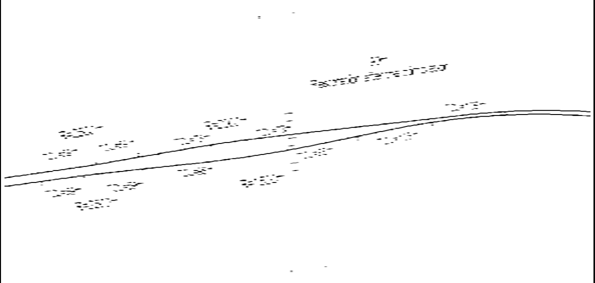
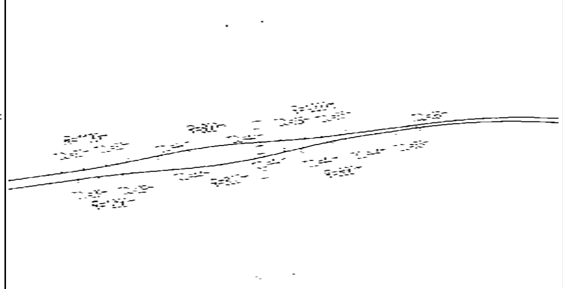
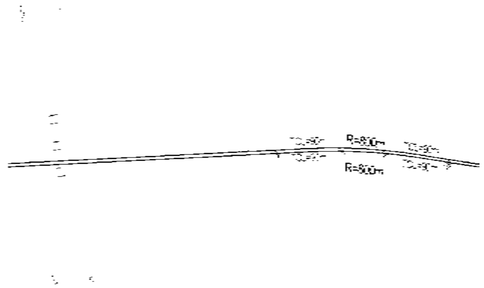
Table 3.4.4 Comparison of proposals on structures near the Ring Road 2

	Plan A	Plan B	Plan C
Schematic diagram			
Outline	Both railroad and road are elevated. Rail line is the outside of road.	Existing road is reduced to 8.5 m from 10.3 m, and railroad structure is constructed.	Both railroad and road are elevated. Whole road is widened. The foundation of railroad and road is laid.
Problem	Land acquisition for railroad is necessary. Alignment of rail line becomes bad because radius of curvature is 200m. When railroad goes back to median strip, huge bridge (span is about 70 m) or gate type pier is needed.	It is necessary to remove the existing piers and stakes. Management of road under construction and temporary bridge are needed. It is necessary to share the foundation of railroad and road (after removal).	Land acquisition for railroad is necessary. It is necessary to remove the existing piers and stakes. Management of road under construction and temporary bridge are needed.
Estimation	「×」: Interference is given to land of residents. Furthermore, alignment of railroad line is bad.	「○」: If the reduction of existing road, the share of the foundation of railroad and road, the management of road under construction and temporary bridge are solved, the proposal is good.	「×」: Since road structure is under construction, it is necessary to consult with residents about widening road width.

	Plan D	Plan E	Plan F
Schematic diagram			
Outline	Railroad is installed into shield tunnel aside existing pier.	Railroads is installed into shield tunnel under new pier and bridge. Existing pier and bridge are once removed.	Railroad is installed into shield tunnel under existing pier. Underpinning process is used.
Problem	It is necessary to pass through residential area.	It is necessary to remove the existing piers and stakes. Manage of road under construction and temporary bridge are needed.	Costruction is relatively difficult.
Estimation	「△」: It is necessary to consult with residents.	「○」: If managent of road under construction is solvable, it is good.	「○」: Although construction is difficult, the work does not influence much the road even if it is under construction.

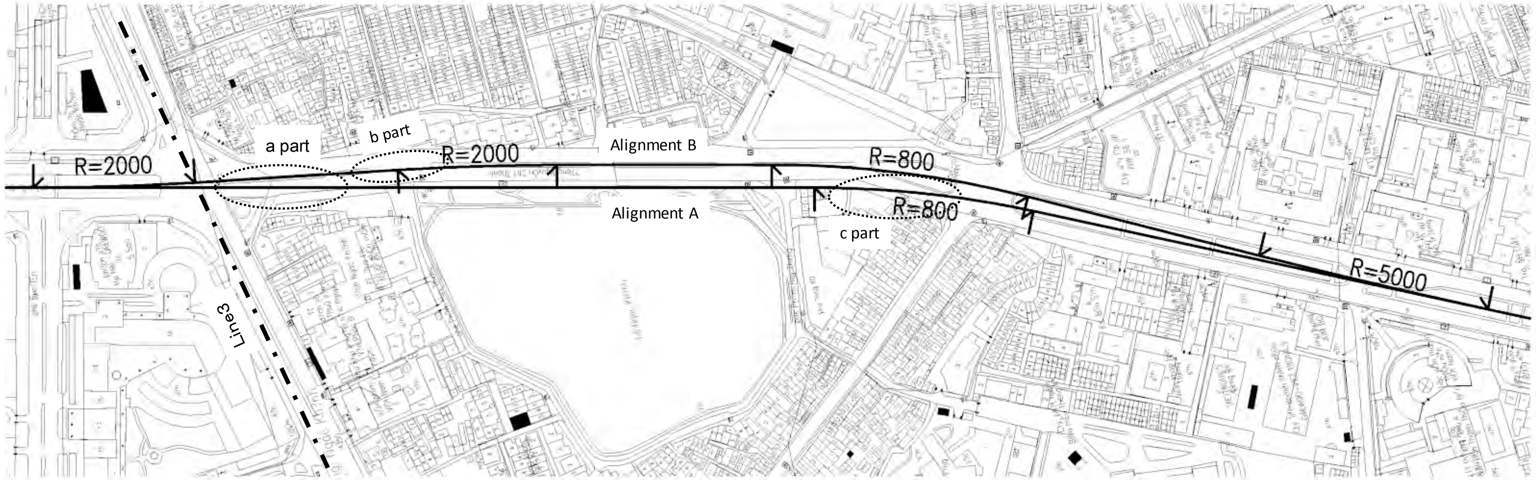
Source: JICA Study Team

Table 3.4.5 Comparison of alignments near the Ring Road 3

	Plan A	Plan B	Plan C
Alignment			
Outline	Plan to construct railroad in the middle of east-bound/west-bound lines in the underpass Maximum speed: 120km/h (setting maximum speed of this section)	Plan to construct railroad in the middle of east-bound/west-bound lines in the underpass Maximum speed: 80km/h	Plan to construct railroad passing by National Convention Center Maximum speed:100km/h
Problems	Need to demolish one part of U-shape retaining wall (about 90 m) at the time of construction Need to resettle drainage pump on the road	There would be limitation on maximum speed Need to resettle drainage pump on the road	Since it is difficult for railway to be constructed on the groundlevel till flyover at the point of 6km050m, St.6 would be underground or semi-underground statons.
Evaluation	"○" as there would be no limitation on alignment	"△" as there would be limitation on the maximum speed. (Noted) "○" if the system is overhead rigid conductor.	"×" as St.6 would be underground or semi-underground statons.

Source: JICA Study Team

Table 3.4.6 Comparison of horizontal alignments near the 1km500m point (in case of elevated structure)

<table>
<tr><th></th><th>Horizontal alignment Plan A (Alignment A)</th><th>Horizontal alignment Plan B (Alignment B)</th></tr>
<tr><td>Schematic diagram</td><td colspan="2">
</td></tr>
<tr><td>Outline</td><td>Center line of railway is straight from the origin and located within a green zone by the side of pond</td><td>Center line of railway is located within narrow median strip (2.9 m including curbstone)</td></tr>
<tr><td>Problems</td><td>- It is not sure whether construction of piers within the green zone is approved.
- At "a" part in the figure, gate-type pillar needs to be constructed.
- At "c" part in the figure, gate-type pillar needs to be constructed, and that leads to resettlement.</td><td>- At "b" part in the figure, where median strip is separated around 50 m, there is a structural problem that span is smaller as compared with width of pier.
- Curved line (R=2000m) will be introduced at the platform of Line3 interconnecting station.</td></tr>
<tr><td>Evaluation</td><td>「△」: Resettlement need to be implemented because of complicated structures of "a" and "c" parts, and the line has to pass through the green zone at theside of pond.</td><td>「○」: there is no need of resettlement. *coordination at the median strip is necessary.</td></tr>
</table>

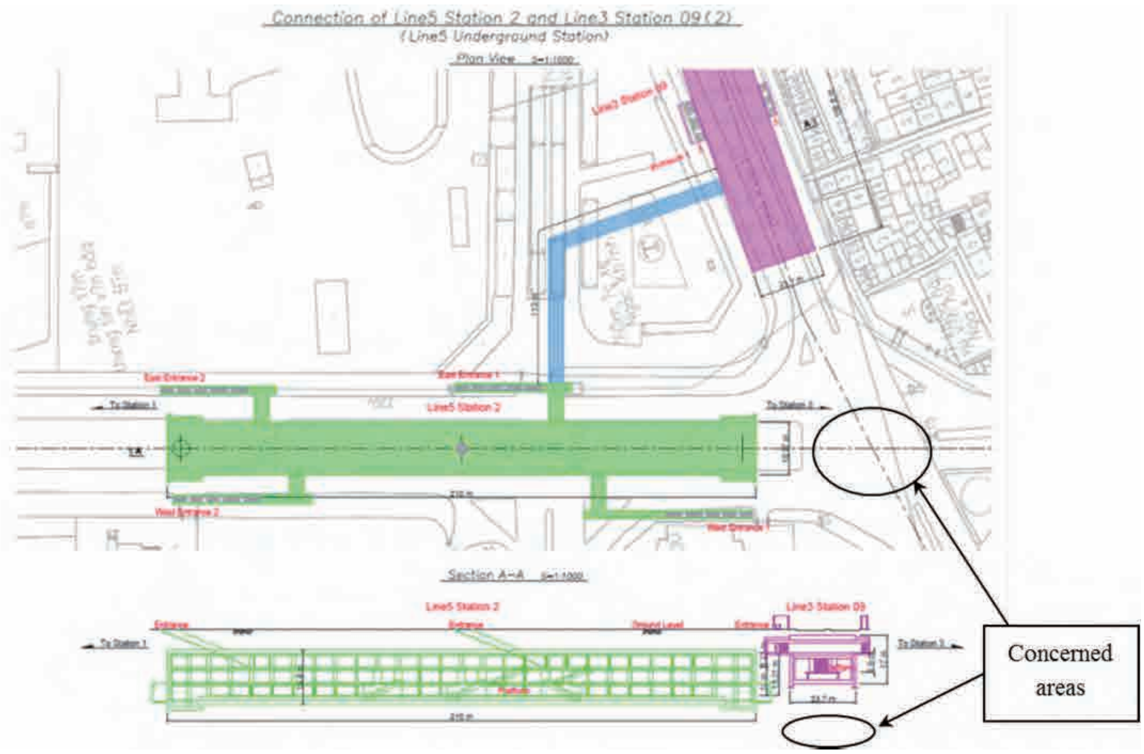
Source: JICA Study Team

(4) Construction method of intersection with Line 3 (for underground structure)

In the route plan of the Line 5, the line intersects with Line 3 at the line end side of St.2. In the route plan of Line 3, it is scheduled that the line changes from an elevated structure to an underground structure at the west side of the Kim Ma Street, and an underground track is constructed with the cut and cover method at the station part including the intersection with the Line 5.

When the structure form of the Line 5 in the midtown area is an elevated structure, there is no problem with adjusting the locations of the piers and foundations of viaducts so that they do not affect the underground building frame of Line 3. However, when the structure form of the Line 5 is an underground structure, the temporary structures for the construction of Line 3 are obstacles.

If the two lines are constructed at the same time, the problem can be resolved through work adjustment before and during the construction. However, the construction of Line 3 will be started before Line 5 according to the schedule, thus the temporary structures of Line 3 shall be considered so that the construction of Line 5 can be performed easily.

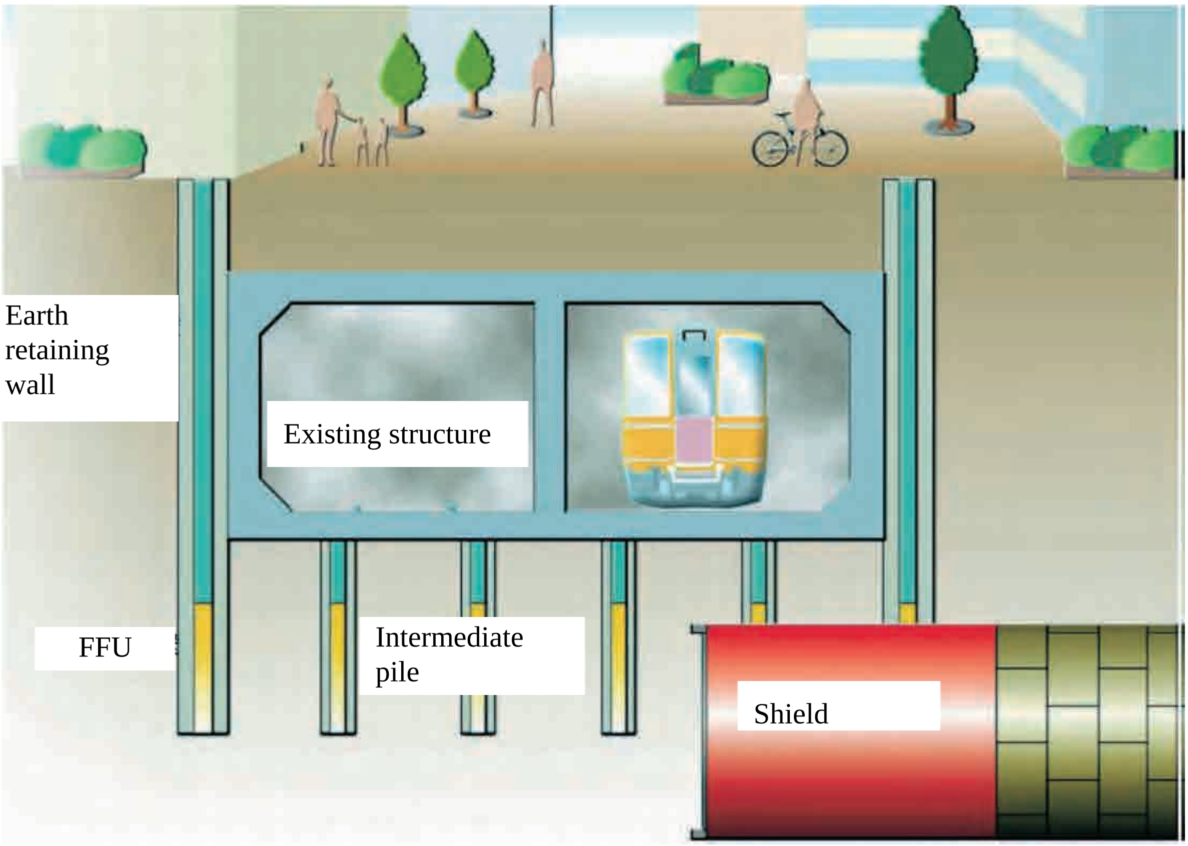


Source: JICA Study Team

Figure 3.4.41 Construction method of intersection with Line 3 (for underground structure)

Here, the shield earth retaining wall system (SEW) method is introduced, which allows direct cutting using a shield machine in the underground construction of Line 5 by incorporating the fiber-reinforced foamed urethane (FFU) members into the earth retaining wall and some of the steel supports of Line 3 beforehand. With this method, although the underground building of the line under operation shall be sufficiently measured, the shield construction is possible just under the underground building where trains are running.

Additionally, there is a similar method, the novel material shield-cuttable tunnel-wall system (NOMST) method using a new type of concrete. Therefore, in the adoption plan of construction method, the field conditions, such as soil property conditions, shall be studied and considered thoroughly.



Source: ZENITAKA Engineering & Works

Figure 3.4.42 Image of SEW method

This construction method is a new shield earth retaining wall system with which the high-strength, durable, and easily workable new material FFU members are incorporated into the area of an earth retaining wall where the shield machine runs through. This method allows, for a vertical shaft, direct cutting of an earth retaining wall using the shield machine and does not require heavy use of auxiliary methods, such as the chemical grouting method, as in the past as well as opening of the earth retaining wall by machine or humans. Therefore, the shield machine can be started and reached safely and reliably. Using this shield earth retaining wall system, when performing construction work just under the existing building at the location in this case, the shield machine allows direct tunneling by incorporating the FFU members beforehand.

3.4.8 Proactive step plan in consideration of future work

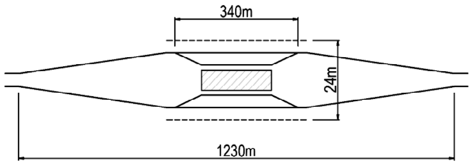
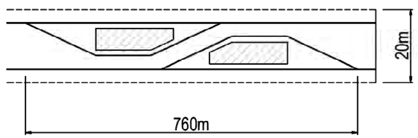
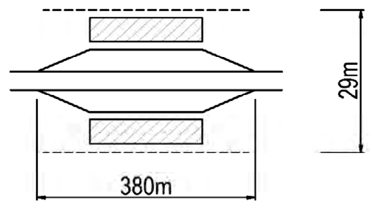
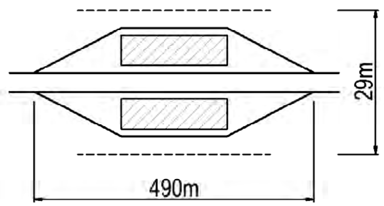
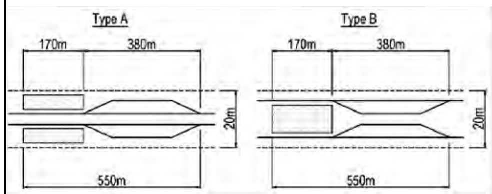
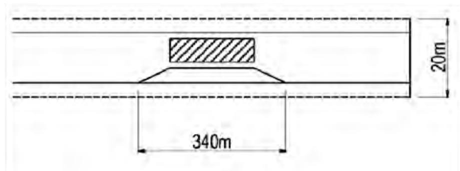
(1) When adding a station

Even when it is necessary to add a station for the Line 5 in case development plan moves ahead in the future, the alignment that allows installation of a platform in the median strip of Thang Long Road to add a station is planned in advance. However, it is expected that it is difficult to connect Ho Tay and Hoa Lac in around 30 minutes when such additional stations increase. In consideration of such a case, the plan allows this line to be developed so that convenience is improved depending on the development along the line without lengthening the time required from the urban area to the suburban area by introducing an express train and setting nonstop stations.

In concrete terms, several plans are conceivable as shown in Table 3.4.7. The ideal plan for the stations is Plan D. With this plan, the connection of an express train and local train (connection from express trains to local ones) is possible, and passengers can change trains. The second ideal plan for stations is Plan A or Plan C. Although these plans do not allow the connection from express trains to local ones, both for the westbound and eastbound lines, an express train can pass through a station while a local train stops at the station. However, even Plans A, C, or D, it cannot be accommodated in the width of the median strip of Thang Long road or 20 m. Due to this situation, several plans were studied that can be accommodated within a width of 20 m. Among the forms studied, Plan B has some problems with the convenience of users and guidance operation because the platforms for the westbound and eastbound are separated.

Consequently, as the result of a study within these restrictions, the conceivable form is similar to Plan E in which a train is evacuated at a location where there is no platform and an express train passes the train or a form similar to Plan F in which passage can be achieved on only one line, although there are some problems when creating the train schedule.

Table 3.4.7 Comparison of overtaking stations

	Plan A	Plan B	Plan C
Diagram			
Outline	Alignment: 1 platform 4 tracks Exterior 2 tracks are non-stop Required width: 24m	Alignment: 2 platforms 2 tracks ×2 (arrange the tracks lengthways) Exterior tracks are non-stop Required width: 20m	Alignment：2 platforms 4 tracks, inside 2 tracks are non-stop Required width：29m
Problems	Does not fit inside the median strip (= 20 m) Leads to widespread influence on roads Impossible to transfer to the trains going to the same direction	Over-track station becomes relatively huge Passengers' accecibility becomes worse (distance to walk inside station becomes longer) Need double elevator/escalator facilities in comparison with the plan of 1 platform	Does not fit inside the median strip (= 20 m) Need double elevator/escalator facilities in comparison with the plan of 1 platform Impossible to transfer to the trains going to the same direction
Evaluation	"×" as the structure does not fit inside the median strip and leads to huge influence on roads.	"△" as the structure fits inside the median strip, but passengers' traffic line becomes longer.	"×" as the structure does not fit inside the median strip
	Plan D	**Plan E**	**Plan F**
Diagram			
Outline	Alignment: 1 platform 4 tracks Exterior 2 tracks are non-stop Required width: 24m	Alignment (Type-A): 2 platforms 2 tracks＋refuge tracks Alignment (Type-B): 1 platform 2 tracks＋refuge tracks Required width: 20m	Alignment: 1 platform 3 tracks (1 track of the one side is passing track) Required width: 20m
Problems	Does not fit inside the median strip (= 20 m) Need double elevator/escalator facilities in comparison with the plan of 1 platform	Local trains which are passed by express trains need to enter the refuge track	Overtaing is possible for only one side of the line (if overtaking for both west-bound/east-bound lines is required, two overtaking stations are necessary.)
Evaluation	"×" as the structure does not fit inside the median strip although function as station is superior	"△" as it is impossible for trains to pass at platforms	"△" as two stations will be required

Source: JICA Study Team

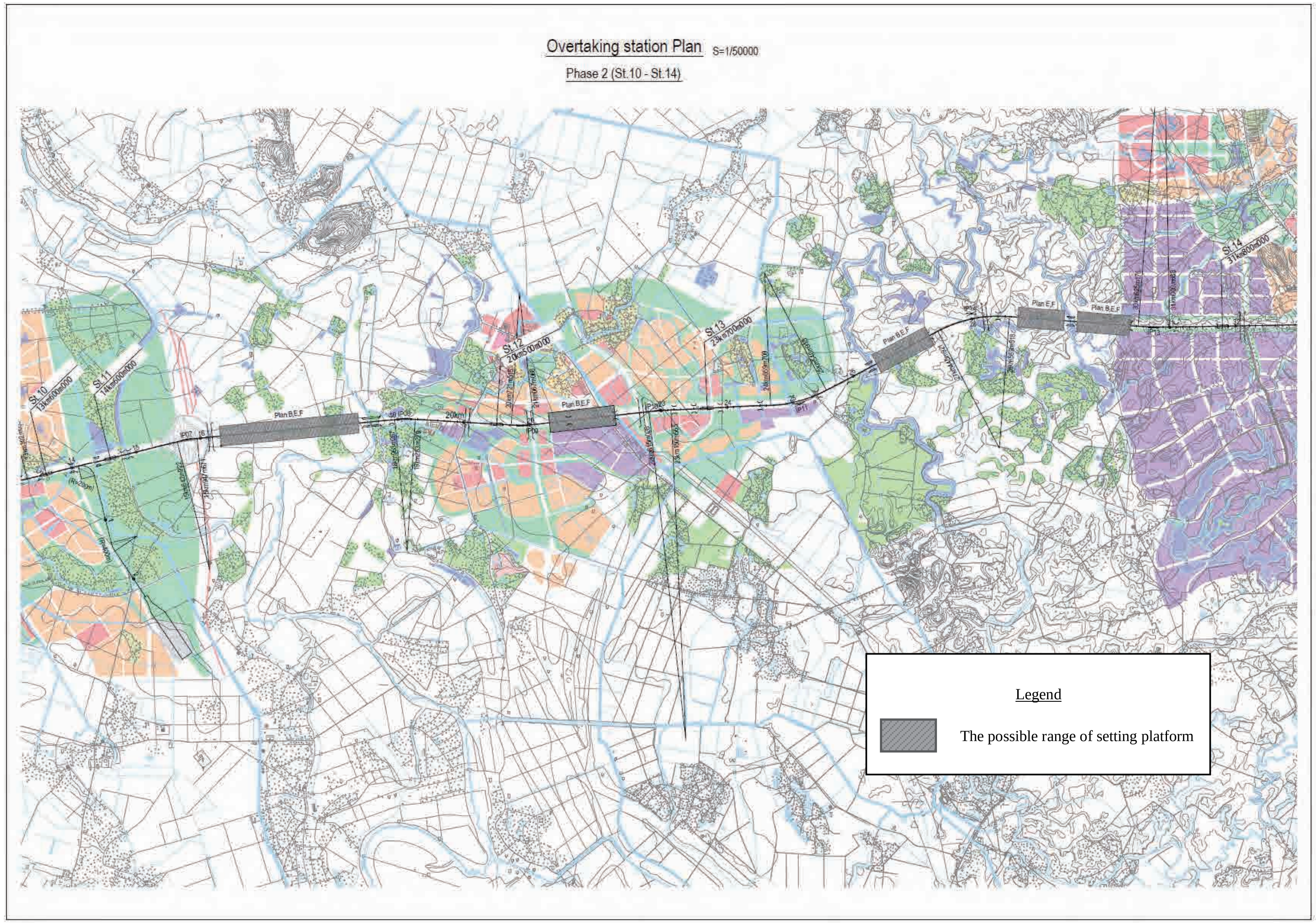


Figure 3.4.43 The area where overtaking stations can be constructed Source: JICA Study Team

(2) Proactive step to enable 160 km/h operation in the future

In the section after St. 6, the train runs over the rail track on the embankment constructed in the median strip of the Thang Long road. This interval consists of relatively shallow curves (R = 2000 m or more) and contains less up and down except for the VNR intersection interval, and the distances between stations are relatively long. Therefore, this interval is suitable for high-speed operation, and this study assumes an operating speed of 120 km in this interval.

When the operating speed increases in the future, it can be realized easily by setting the length of the transition curve to a large value beforehand. If R = 2,000 m, the length of the transition curves for 130 km/h and 160 km/h are TCL(130) = 93 m and TCL(160) = 174 m, respectively. When determining or locating a curve or turnout on the line plan, this fact shall be considered.

In the signal plan, introduction of wireless train position detection is assumed. Therefore, when the trains run at 160 km/h in the future, only the software shall be modified, and there will be no change in the location plan for wireless devices.

(3) Proactive step to enable connection with Line 6

After the operation of Line 5 is started, it is expected that various new lines will be constructed or extended in the future. In such cases, connection with Line 6 can be achieved flexibly by taking all conceivable measures into account. It is thought that this will contribute to the enhancement of Hanoi's railway network.

As for the connection from the Line 5 into Line 6, although there are problems of land acquisition and gauge, it is thought that it is significant to study the possibility of the plan because Noi Bai International Airport and Hoa Lac will be connected directly. The location of St.9 was planned to enable connection with the Line 6. Specifically, it was planned so that a sufficient interval required to install the connecting line is secured, and the layout of stations is well balanced when a new station is added at the VNR intersection.

Source: JICA Study Team

Figure 3.4.44 Plan of connecting line with Line 6