Data Collection Survey on the North-South High Speed Rail Project in the Socialist Republic of Vietnam

Final Report (Executive Summary)

Disclosure Document

October 2019

JAPAN INTERNATIONAL COOPERATION AGENCY

PADECO Co., Ltd.
Yachiyo Engineering Co., Ltd.
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Figures on cost estimation and economic/financial analysis have been removed because of confidential information.

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Abbreviations

AC	Alternating Current
AFTA	ASEAN Free Trade Area
ASEAN	Association of Southeast Asian Nations
AT	Auto Transformer
ATC	Automatic Train Control
ATP	Auto-Transformer Post
ATS	Automatic Train Stop
B/C	Benefit-Cost Ratio
BT	Booster Transformer
CAPEX	Capital Expenditure
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
CS	Copper-Clad Steel
DAC	Development Assistance Committee
DS-ATC	Digital communication & control for Shinkansen-ATC
EIRR	Economic Internal Rate of Return
EVN	Vietnam Electricity
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
HCMC	Ho Chi Minh City
HSR	High Speed Rail
IE	Institute of Energy
IGBT	Insulated Gate Bipolar Transistor
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JNR	Japanese National Railways
LCX	Leaky Coaxial Cable
LRT	Light Rail Transit
MOIT	Ministry of Industry and Trade
MOT	Ministry of Transport
NPV	Net Present Value
OD	Origin Destination
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
O&M	Operation and Maintenance
PC	Prestressed Concrete
PC	Programmable Controller
PMU	Project Management Unit
PPP	Public-Private Partnership
PWM	Pulse Width Modulation

RC	Reinforced Concrete
RCEP	Regional Comprehensive Economic Partnership
SCF	Standard Conversion Factor
SP	Sectioning Post
SPC	Specific Purpose Company
SSP	Sub-Sectioning Post
TEDI	Transport Engineering Design Inc.
TOD	Transit Oriented Development
UIC	International Union of Railways
USD	United States Dollar
VITRANSS2	The Comprehensive Study on the Sustainable Development of Transport System in Vietnam
VNR	Vietnam Railways
VHSR	Vietnam High Speed Rail
VVVF	Variable Voltage Variable Frequency

Executive Summary

1. Overview of the Project

1.1 Background of the Project

For Vietnam, which has achieved remarkable economic growth in recent years, the North-South High-Speed Railway (hereinafter referred to as "HSR") Project is expected to be a catalyst for further development, and serve as a symbol of the country's economic success.

Although the cabinet initially decided in March 2010 to construct the HSR based on the Japanese Shinkansen system; this decision was not approved by the Vietnam National Assembly (VNA) which was held in May later that year. The following 5 points were requested in the VNA to be further addressed; i) necessity of investment, ii) effectiveness of the project, iii) socio and environment consideration, iv) implementation options, and v) HSR technology options.

Over the period of 2010-2013, JICA implemented the survey of "North-South High-Speed Railway Construction Plan Formulation Project" (hereinafter "previous study") and formulated the project plan for the two priority sections (Hanoi – Vinh and Nha Trang – Ho Chi Minh section) by examining the alternatives and selecting the optimal plan.

At the end of 2016, the Vietnamese government decided to re-submit the project to VNA and requested the Japanese government to update the previous studies and implement a supplemental survey to assist the Vietnamese government in preparing a Pre-F/S to be submitted to the VNA.

Against this backdrop, in order to prepare sufficiently for VNA deliberations, the JICA Study Team has reorganized the contents of the past survey and updated the information in cooperation with local consultants assigned by the Ministry of Transport (hereinafter referred to as "local consultants"). The study period is from December 2017 to September 2019.

1.2 Objective of the Survey

The objective of this survey is to assist the Ministry of Transport in preparing the Pre-F/S in joint cooperation with the local consultants, which is to be submitted to the VNA.

1.3 Implementation of the Survey

The JICA Study Team signed the meeting minutes with the Project Management Unit (PMU) under MOT and decided on the role sharing between both consultant parties, survey process, seminars to be held, due dates of report submissions, etc. The JICA Study Team cooperated with the local consultants to review the contents of the previous study, update the information and analysis, and support their preparation of the Pre-F/S to be submitted to the VNA.

In the memorandum, the reports were set to be submitted to MOT by the local consultants, and the JICA Study Team was to support the local consultants by providing relevant materials and conducting analysis which required advanced technical capabilities. The reports are categorized into main reports and specialized reports. The former consists of the standard inception report (IC/R), interim report (IT/R), draft final report (DF/R), and final report (F/R). The latter consists of four technical reports focusing on: the necessity of investment (SP1); selection of high-speed railway technology and train operation plan (SP2); economic/ financial analysis and investment plan (SP3); and operation/management organization, human resource, and development of railway industry (SP4). It was requested by the local consultants that the JICA Study Team aid in particular with conducting the demand forecast, the selection of the HSR technologies, and the economic/financial analysis.

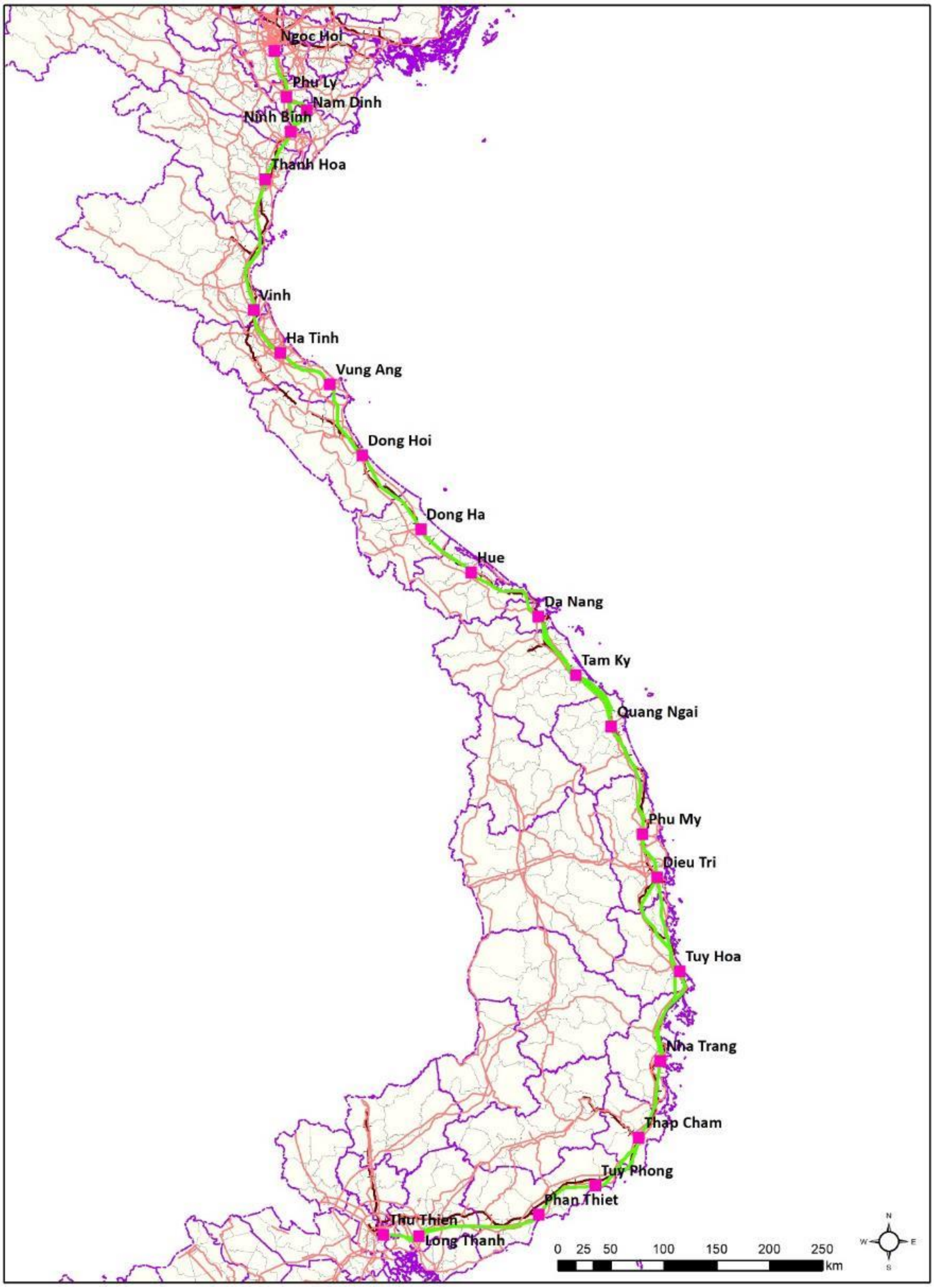
The JICA Study Team occupied a room in the building of the local consulting firm, which enabled constant consultations with the corresponding counterparts during their stay. Upon returning to Japan, discussions via email and Skype continued. The survey team transferred their technologies to the local consultants as much as possible by providing relevant documents and calculation files, so that local consultants could further answer questions from the VNA. The workflows of this survey and the sharing of roles between the JICA Study Team and the local consultants are shown below.

Table S-1: Workflows and Roles Sharing between JICA Study Team and Local Consultants

No.	Seminar Date	Report	JICA Study Team	Local Consultants
1	20 March 2018	IC/R	Organize the results of existing studies and major issues.	
2	4 July 2018	SP1	Forecast the traffic demand.	Organize infrastructure development plans.
3	20 July 2018	SP2	Examine the Semi-HSR, mix use of passenger and freight train on HSR, night train, and function sharing with conventional railway.	Organize the other countries' technologies and their application.
4	25 August 2018	IT/R	Consolidate the discussions and estimate the project cost.	Re-examine the route and stations' location, and estimate the civil cost.
5	24 September 2018	SP3	Examine the project scheme and financing options, and conduct economic/financial analysis.	Organize the other countries' project schemes and their application.
6	11 October 2018	SP4	Organize Japanese experiences on operation/ management organization, human resource, and development of railway industry.	Organize the other countries' cases.
7	12 November 2018	DF/R	Consolidate the discussions.	Prepare report and presentation.
8	February 2019 *Report submission	F/R	Consolidate the discussions.	Prepare report and presentation.

Source: JICA Study Team

The project area map is shown in the following figure.



Source: JICA Study Team based on the data prepared by the local consultants

Figure S-1: Project Area Map

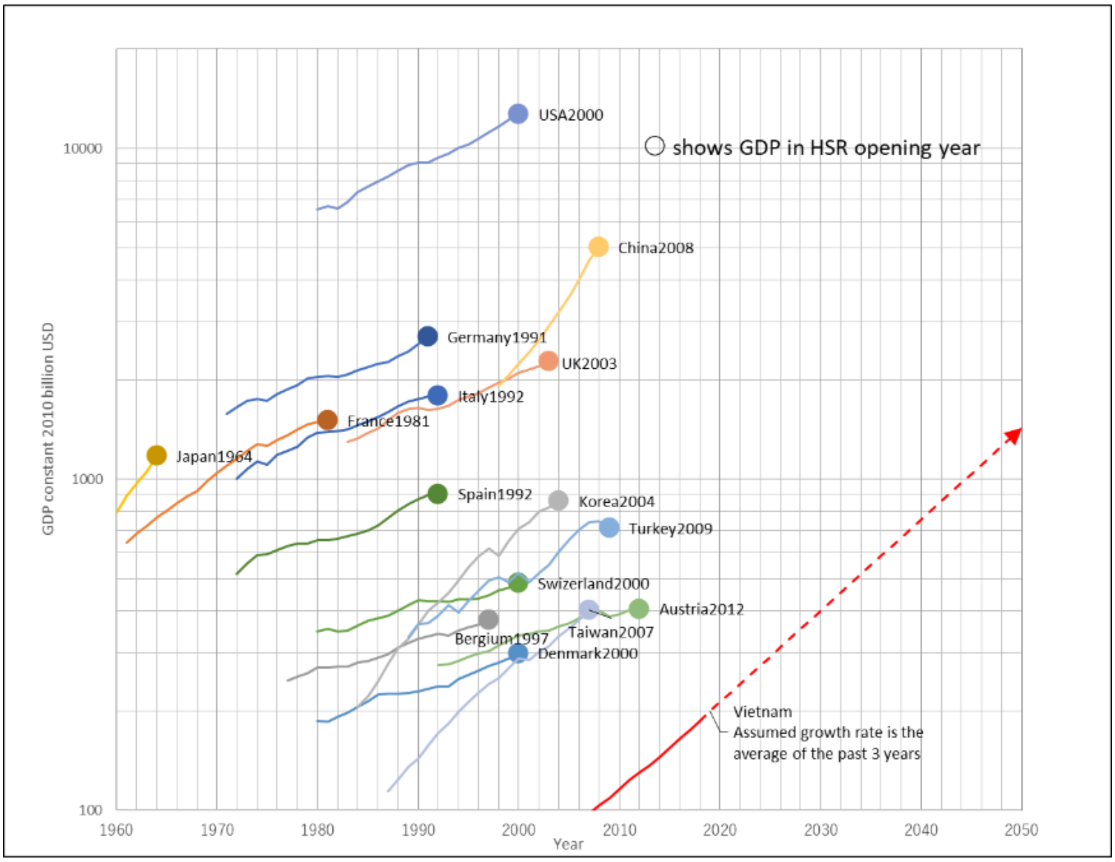
2. Necessity of Investment

2.1 GDPs with HSR of Other Countries

Although there is no definite classification for HSR, UIC calls railways that operate over 250 km/h on new lines, and over 200 km/h on improved conventional lines as HSR.

The figure below shows the relation between the opening year of HSR and GDP. The dotted red line indicates the trend of GDP in Vietnam on the assumption that the future growth rate is the average of the past 3 years.

By 2030, Vietnam's GDP is forecasted to reach 400 billion USD, which is the GDP level of other countries when they launched HSR. Therefore, opening HSR in 2030 seems appropriate.



Source: JICA Study Team based on World Development Indicators (WB, 2018) and High-Speed Lines in the world 20th (UIC, 2018)

Figure S-2: GDP in HSR Opening

2.2 Forecast of Transportation Demand

2.2.1 Construction Case

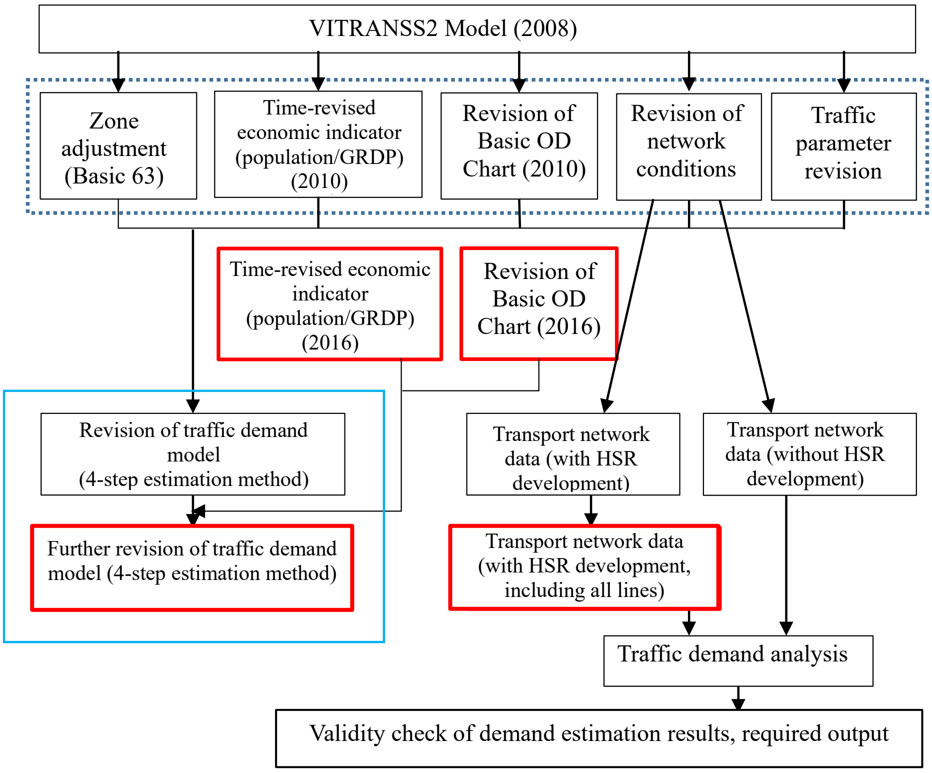
This project is extensive, covering a total length of 1,541 km and requires a huge amount of money and effort. The JICA Study Team considers two construction cases;

Two -step Case plans to divide the whole line into three sections, to open Hanoi – Vinh in the north section and Nha Trang – Thu Thiem in the south section by 2030, and Vinh – Nha Trang by 2040.

Five -step Case plans to divide the entire line into 5 sections, to open a single-track line between Long Thanh – Thu Thiem by 2030, then Hanoi – Vinh by 2040, Nha Trang – Thu Thiem by 2050, Da Nang – Nha Trang by 2060, and Vinh – Da Nang by 2070.

2.2.2 Methodology of Forecasting

Transportation demand is calculated by the updated model of VITRANSS2 considering the latest socio-economic indices and basic OD table.



Source: JICA Study Team revision of the previous study (JICA, 2013)

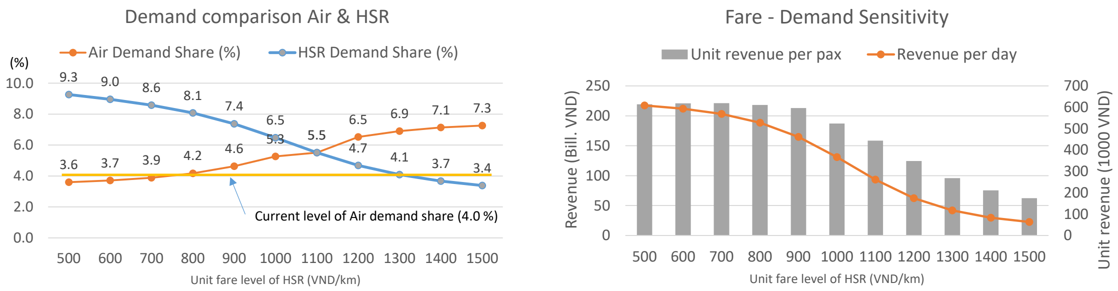
Figure S-3: Methodology Flow of Revision for Traffic Demand Analysis

(1) Time and Cost Factors

Fare/cost value of every transportation mode has been updated using the growth rate figures of the previous study.

(2) HSR Fare Sensitivity

HSR fare unit is set at 900 VND/km as a result of sensitivity analysis, in consideration of the fare balance between air and existing rail.

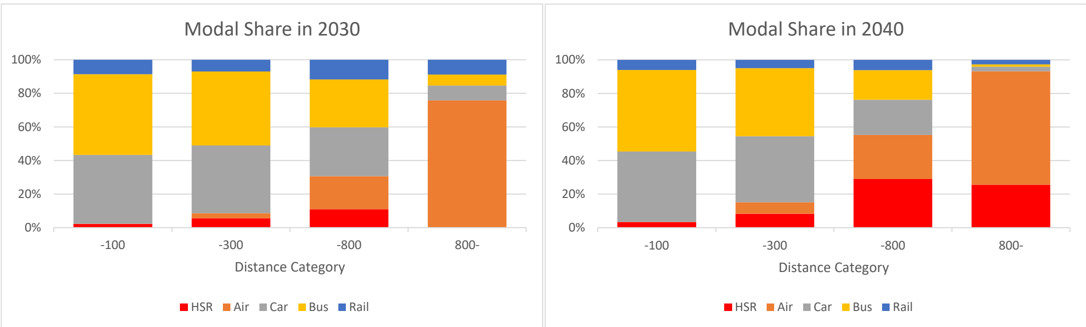


Source: JICA Study Team

Figure S-4: HSR Fare Sensitivity Analysis

(3) General Features on Transportation Modal Split

The HSR system has an advantage for middle range distance (300 km–800 km) compared with other transportation modes.

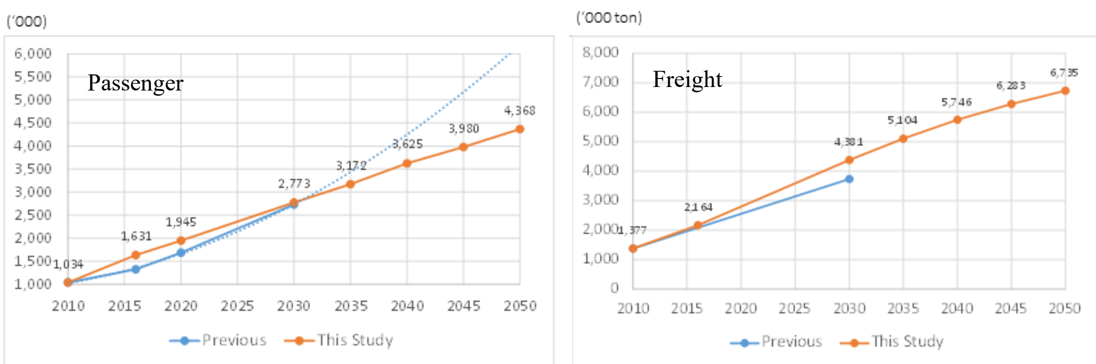


Source: JICA Study Team

Figure S-5: Modal Split by Distance Category by Transportation Mode

2.2.3 Updated OD Matrix

Passenger volume for all transportation modes will be moderately increased against the rate of the previous setting. The increasing rate of freight volume will be larger than the previous estimate.



Source: JICA Study Team

Figure S-6: Total Passenger Trip Demand of Target Years in Vietnam

2.2.4 Planning of the Various Transport Modes

Table S-2: Target Transport Modes and Development Case of Existing Railway

Mode	Description
Airport	Phase 1 operation of Long Thanh International Airport in 2025
Railway	Several improvement cases for North-South existing railway
Roads	New construction and improvement for Highway, National Rd. No. 1, Coastal Rd., and Hanoi - Ho Chi Minh Rd.

Source: Vietnam Business Vol. 23 (Lai Vien Co., Ltd, 2012)[1], JICA Study Team, the local consultants

Table S-3: Development Levels of Existing Railway

Level	Services of Existing Railway	Scenario Analysis
A1	Single Track, Gauge 1,000 mm, Maximum Operation Speed approx. 60 km/h	Not included. A1-level development is currently ongoing.
A2	Single Track, Gauge 1,000 mm, Maximum Operation Speed approx. 70 km/h	Included.
B1	Double Track, Gauge 1,000 mm, Maximum Operation Speed approx. 120 km/h	Not included. Less economic impact than A2 (JICA, 2013).
B2	Double Track, Gauge 1,435 mm, Maximum Operation Speed approx. 200 km/h[2]	Included.

Source: Previous Study (JICA, 2013)

In the previous study, the demand forecast was conducted assuming four (4) levels for the development of the existing railway. In this survey, based on discussions with the local consultants, development levels A2 and B2 of the existing railway are incorporated into scenario analysis.

Table S-4: Development Scenario for Existing Railway and HSR

Scenario	Existing Railway	High-Speed Rail
Scenario 1	A2	None
Scenario 2	B2	None
Scenario 3	A2	Passenger only, Maximum Speed 350 km/h

Source: JICA Study Team

Based on discussions with the local consultants, three (3) development scenarios shown in Table S-4 were set. Scenario 1 assumes the situation where the existing meter-gauge and single-track railroad is improved so that trains are enabled to operate at 70 km/h. Scenario 2 assumes the situation where the existing meter-gauge and single-track railroad is reconstructed as a standard-gauge and double-track so that trains are enabled to operate at 200 km/h. Scenario 3 assumes the situation where the existing meter-gauge and single-track railroad is improved so that trains are enabled to operate at 70 km/h and where HSR is constructed and operates at 350 km/h.

Scenarios 1 and 2 assume the improvement of the existing railway to confirm whether to fulfill future traffic demand without HSR. Scenario 3 assumes the HSR development.

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[1] Lai Vien Co., Ltd. (2012). Overcrowded Tan Son Nhat International Airport and Long Thanh New International Airport Plan (Part 2). *Vietnam Business Vol. 23*. http://www.laivien.com/uploads/access/Vol.23.pdf. Accessed on 1 July 2019. (only in Japanese)

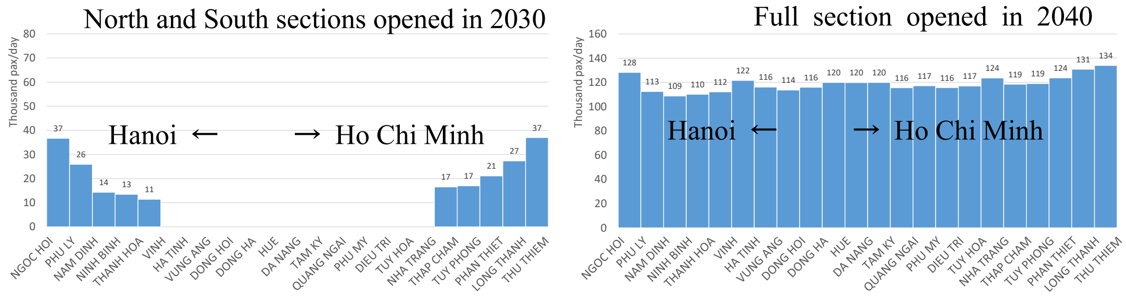
[2] In the previous survey (JICA, 2013), the maximum operation speed at B2 level was 150 km / h. In this survey, demand forecast was conducted assuming that the maximum operation speed at B2 level was 200 km / h based on consultations with the local consultants.

2.2.5 Forecast Results (Two-step Case[3])

The assumption that existing rail would be improved with A2 level, i.e., Single track, 1,000 mm gauge, and Maximum speed approx. 70 km/h.

(1) Sectional Demand

Sectional demand for both the temporary stage in 2030 and full operation stage in 2040 is as follows.

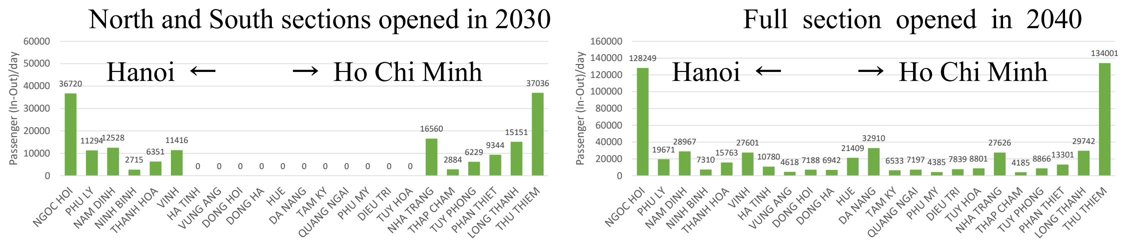


Source: JICA Study Team

Figure S-7: Sectional Demand of HSR in 2030 and 2040

(2) Passenger Demand at Proposed Stations

The passenger demand at proposed stations for both the temporary stage in 2030 and full operation stage in 2040 is as follows.



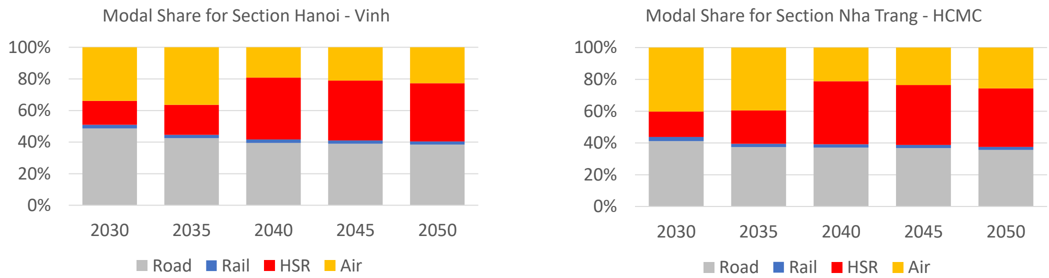
Source: JICA Study Team

Figure S-8: Passenger Demand at Proposed Stations of HSR in 2030 and 2040

(3) Transport Modal Share

The modal share of HSR is estimated at approximately 15% for the temporary stage and approximately 40% for the full operation stage.

[3] Two (2) -step Case plans to divide the whole line into three sections, to open Hanoi – Vinh in the north section and Nha Trang – Thu Thiem in the south section by 2030, and Vinh – Nha Trang by 2040.



Source: JICA Study Team

Figure S-9: Transport Modal Split for Scenario 3

(4) Capacity and Demand Gap Assessment for all Transportation Modes

Scenario 1 assumes the situation where the existing meter-gauge and single-track railroad is improved so that trains are enabled to operate at 70 km/h. Simulation result of scenario 1 shows that the existing railways and aviation lines will have a marked shortage of infrastructure capacity from 2030.

Scenario 2 assumes the situation where the existing meter-gauge and single-track railroad is reconstructed as a standard-gauge and double-track so that trains are enabled to operate at 200 km/h. Simulation result of scenario 2 shows that the shortage of capacity will appear from 2030 and will be expanded accompanying increase in traffic demand thereafter.

Scenario 3 assumes the situation where the existing meter-gauge and single-track railroad is improved so that trains are enabled to operate at 70 km/h and where HSR is constructed and operates at 350 km/h. Simulation result of scenario 3 shows that the transport capacity can be covered approximately. HSR requires huge investments, so prioritized sections including North section (Hanoi – Vinh), and South section (Nha Trang – Ho Chi Minh) are recommended to be developed in 2030 as an initial phase. The remaining sections are recommended to be constructed in the 2040s and operation of the entire section will begin thereafter.

Table S-5: Section Capacity and Demand Gap for Transport Modes

2030	Scenario	Modes	Section		
			North	Central	South
No HSR	Scenario 1	Roads	OK	OK	OK
		Existing rail	×	×	×
		HSR	-	-	-
		Air	×	×	×
	Scenario 2	Roads	OK	OK	OK
		Existing rail	△	×	△
		HSR	-	-	-
		Air	OK	×	OK
HSR (North, South)	Scenario 3	Roads	OK	OK	OK
		Existing rail	OK	△	OK
		HSR	OK	-	OK
		Air	OK	×	OK

2040	Scenario	Modes	Section		
			North	Central	South
No HSR	Scenario 1	Roads	OK	OK	OK
		Existing rail	×	×	×
		HSR	-	-	-
		Air	×	×	×
	Scenario 2	Roads	-	-	-
		Existing rail	×	×	×
		HSR	-	-	-
		Air	OK	OK	OK
HSR (Full)	Scenario 3	Roads	OK	OK	OK
		Existing rail	△	△	△
		HSR	OK	OK	OK
		Air	OK	OK	OK

Source: JICA Study Team

2.2.6 Conclusions and Recommendations (Two-step Case)

Capacity shortage on the north-south corridor will occur after 2030 even if existing rail infrastructure is upgraded to a double-track (B2 level). This shortage will be worse specifically for rail and freight, so the introduction of HSR to cover long distance trips across Vietnam is an effective solution. However, even if HSR is developed in conjunction with the improvement of existing rail with A2 improvement plan (single track improvement), a small lack of transportation capacity with the projected rail infrastructure will still exist. To cope with this issue, it is necessary for existing rail infrastructure to double-track the bottleneck sections.

2.2.7 Alternative Case Results (Five-step Case[4])

The characteristics of the passenger volume of HSR for Five-step Case is almost the same, where a drastic change in the passenger volume may occur after the completion of the entire line from Hanoi to Ho Chi Minh. Although it may be reasonable to construct the HSR depending on financial availability, large scale social benefit cannot be expected until all sections from North to South (i.e., Hanoi – Ho Chi Minh) are connected.

Table S-6: Passenger Volume of HSR for Five-step Case

Year	Section	Passenger Volume (Pax/day)
2030	Long Thanh – HCMC (Single track)	10,521
2040	Hanoi – Vinh, Long Thanh – HCMC	65,063
2050	Hanoi – HCMC, Nha Trang – HCMC	127,670
2060	Hanoi – HCMC, Da Nang – HCMC	200,532
2070	Hanoi – HCMC (Full)	396,953

Source: JICA Study Team

[4] Five-step Case plans to divide the entire line into 5 sections, to open a single-track line between Long Thanh – Thu Thiem by 2030, then Hanoi – Vinh by 2040, Nha Trang – Thu Thiem by 2050, Da Nang – Nha Trang by 2060, and Vinh – Da Nang by 2070.

3. Basic Requirement of HSR System

3.1 HSR Standards

There are various aspects to consider with HSR systems such as the direct operation with conventional lines, the traction system, and the safety standards; and each system applies its own standards.

The recommended standards for HSR in Vietnam and the reasons are listed below.

Table S-7: Recommended Standards for HSR in Vietnam

No.	Specifications		Reason
1	Design Maximum Speed	350 km/h	Common in the world.
2	Maximum Service Speed	320 km/h	Highest speed of Japan and Europe.
3	Design load	P-16	Reduces construction costs as a passenger dedicated line. Same load as Shinkansen considering the flexibility of vehicle selection.
4	Track Spacing	4.3 m	Smaller and more economical than HSR in Europe. Same spacing as Shinkansen.
5	Minimum Curve Radius	6,000 m	Consistent with the design maximum speed.
6	Cant Maximum	180 mm	Safety and riding comfort, same as Shinkansen.
7	Steepest Gradient	15/1000	Good balance between operating performance and cost. Standard gradient of Shinkansen.
8	Formation Width	11.7 m	Reduction of construction and land acquisition cost. Experience in Shinkansen.
9	Track Structure	Ballast/Slab	Ballast on earth structures for possible subsidence. Slab in tunnels and viaducts for reduction of maintenance.
9-1	Rail	60 kg/m	Reduction of maintenance by heavy rail. Experience in Shinkansen.
9-2	Turnout	#18	Good balance between train speed and maintainability. Same as Shinkansen.
9-3	Ballast Thickness and Track Slab	300 mm/ flame-shaped slab	Reduction of cost for both construction and maintenance. Experience in Shinkansen.
9-4	Sleeper	43 sleepers/25 m	Experience in Shinkansen.
10	Cross Section of Tunnel	64 m^2	Smaller and cheaper than that of China and Europe Experience in Shinkansen.
11	Signal	VHSR-ATC Digital Radio ATC	Improved ATC corresponding to two-way operation; Even though it is on the way to practical use, the prototype is attached to Tohoku Line, and the confirmation test is scheduled.
12	Communication	Digital Train Radio	Continuous and stable communication by LCX.
13	Power	AC 25 kV	Cost reduction by long substation intervals using high voltage. Experience in Shinkansen.

Source: JICA Study Team

The standards applied to high-speed railways are determined in consideration of the surrounding environment and the applicable technology. The former includes noise regulation, anti-seismic measures, and ground conditions, etc.; meanwhile, the latter considers the axial weight, the construction base width, and the tunnel cross-section, etc. The cost of construction is mainly dependent on the applied standards.

3.2 Role Sharing Between HSR and Conventional Lines

In the previous study (JICA, 2013), the direction for the improvement of the railway in the North-South Corridor was as follows below, and its validity was supported in the demand forecast of this survey.

(1) The high-speed railway shall be constructed with a new line dedicated to passengers, and the completion of the entire line is a long-term target.
(2) The improvement of the existing line shall be completed from 2020-25, which maximizes the line capacity of the single track, responding to passenger and cargo demand during this period.
(3) In the sections where demand is high, it may be possible to install double-tracking. Freight and local passenger transport demand would require further consideration at appropriate times.

3.3 Consideration of Mixed Cargo Train Operation on the High-Speed Railway Line

When high-speed passenger trains and freight trains are operated at the same time, the operable number of trains is hugely reduced due to the differences in speed. Also, there is a possibility that cargo loaded on freight cars can fall off, due to train draft from high-speed trains and cause serious accidents. For these reasons, separating the traveling time zones of passenger trains and cargo trains, and limiting the operation of cargo trains to night-time is an unavoidable measure[5].

Since the distance between Hanoi and Ho Chi Minh is around 1,541 km, freight trains shall only be operated at night and stop on the storage line during the day. As a result, the speed of the freight train would decline, and the operation efficiency would decrease even if many vehicles are used, affecting the investment profitability.

3.4 Influence of Train Speed on Investment and Operation Cost

In the study, two options of train speed at the opening stage are compared. One is to operate the railway at 320 km/h; another is to start operation at 200 km/h and improve the speed up to 320 km/h when the whole line is connected.

In the latter case, O&M expenses (power costs and track maintenance fees) during partial opening are reduced by 10% of O&M expenses. On the other hand, vehicle operation efficiency decreases as the speed decreases, and vehicle procurement costs increase by 4% of vehicle acquisition expenses.

Considering the demand reduction due to the 200 km/h operation and the work for adjusting the cant, it does not seem reasonable.

3.5 Night Train Operation

The time required for Hanoi - Ho Chi Minh is about 5 hours 30 minutes by express train. Approximately 30% of passenger demand tends to prefer night trains according to the Report of the Sanyo Shinkansen Technology Investigation Committee (JNR, 1966).

The operation of night trains would affect track maintenance works every night. It is indispensable to introduce a signaling system for two-way operation, and to make one track exclusively for maintenance.

[5] Such a measure is also taken in Germany running cargo trains on high-speed rail lines.

4. Route Planning and Development along the Line

4.1 Design Criteria

The design criteria are set as shown in the following table. The effect of increased speed is significant for this route because of the long distance (1,541 km). The design speed in accordance with the fastest category in the world should be adopted.

Table S-8: Design Maximum Speed

Item	Setting value
Maximum Speed	350 km/h
Maximum Operational Speed	320 km/h
Design Load	P-16
Distance between Track Centers	4.3 m
Maximum Cant	180 mm
Minimum Curve Radius	6,000 m
Maximum Gradient (Inevitable case)	15‰ (25‰)
Formation Width	Both side aisle 11.7 m, One side aisle 11.2 m.
Track Structures (Viaduct, Tunnel)	Slab track
Track Structures (Earth structure)	Ballast track

Source: JICA Study Team

4.2 Route

4.2.1 Route between Stations

The HSR route is set based on the results of the F/S in 2009 and the previous study (JICA, 2013). With the change of the station site in this survey, the route between stations was also changed by the local consultants. The route plan proposed in the study was confirmed to be consistent with basic matters of route alignment planning. However, the route may change based on discussions with local governments in the course of delivering the HSR.

More detailed studies were done in two places of particular concern. 1) Around Hue station: To avoid areas where many historic relics are buried and 2) Around Hai Van Pass: Regarding plan alignment and the length of tunnels because the region has many tunnels.

4.2.2 Track Alignment

Two types of layouts are applied; one is “Two island platform with four lines” for larger stations, and the other is "Two side platform with four lines." For the terminal stations (Ngoc Hoi, Thu Thiem), a maintenance platform for cleaning the vehicles inside shall be equipped.

4.3 Station Site Planning

A total of 23 station sites have been selected under the previous study for the North-South HSR development. The following criteria were taken into consideration for each proposed station site and physically analyzed by its city and urban development conditions, spatial relationship to the city center, bus terminals & railway station, technical issues (such as intersecting conditions with rivers, canals, roads, other infrastructures, etc.), and land uses.

- There is social and economic development potential for the target cities and surrounding regions through the development of an HSR station.
- There could be relatively easy and effective transits and networking between railways and roads.

- There are no major discrepancies or conflicts with the upper or superior national and regional development plans, indicating the synergic development effect could be expected with these plans.
- The station sites do not have any major obstacles with land acquisition and resettlement.
- Standard station to station distance is considered as around 50 km. For stretches where station distance exceeds 50 km, a track maintenance station should be located, if necessary.

The site inspections indicated that there are some issues regarding land acquisition/ resettlement with the station site areas. However, there could be solutions to these issues, such as rearranging alignment or adjusting station location. The following table describes current activities regarding the areas around the target station sites.

Table S-9: Current Situation around Station Sites

	Station Name	Additional Information
1	Ngoc Hoi (Hanoi)	MOT considers a new concept of extending the alignment from current Ngoc Hoi station site to Hanoi railway station in the city center. When the HSR Hanoi station is realized, passenger convenience will be drastically increased. However, land acquisition is a major issue, and the proposed solution is to share the structure with the Hanoi metro line No. 1. If this plan could be made possible, there would be significant benefits to railway networks in Hanoi, including metro line No. 1.
2	Vinh	The station site relocation is considered by the local government southbound from the current location.
3	Hue	The proposed station site is located near the historic castle city. The local government has requested to study TOD with effective landscape preservation.
4	Da Nang	The local government has the relocation plan of the existing station, and it may come together with the proposed HSR station. However, the proposed site is occupied by a large number of illegal residents, so the land acquisition could be a major issue as noted by some officials.
5	Dung Quat	There are ongoing developments of a trade port and industrial zones near the proposed station site. The local government needs to analyze the necessity of HSR station in this area.
6	Nha Trang	The proposed station site is at the existing railway station of Nha Trang. The local government is studying the area west for HSR station, and a TOD study has been requested by the government.
7	Thu Thiem (Ho Chi Minh)	MOT and the local government is studying the possibility of a direct connection to Saigon station in the city center. Also, further extension of HSR to Can Tho is considered as future development potential.

Source: JICA Study Team

Taking the above into account, further recommendations to station site planning are summarized hereafter.

4.3.1 Ngoc Hoi

It is important to improve and expand the industry and function of government administration in the capital of Hanoi. For this purpose, the development of effective public transportation systems integrated with HSR is useful. Ngoc Hoi station is very far from the city center of Hanoi, so shortening such physical distance is necessary by developing suitable transportation system to connect them. Early decision making is necessary for the future development of the HSR network to integrate with the current on-going development of Metro Line-1 project.

4.3.2 Vinh

Vinh city acts as not only a tourism destination but also as a connection hub to Laos. The airport is also located close to the city center. Therefore the HSR station should be as close as possible to the urban center of Vinh for better transport service and convenience for users. The city is expected to undergo further economic development through the air service connections to the southern regions.

4.3.3 Hue

As the city of Hue has grown well as a tourist destination, it is important to develop the HSR structure in deep consideration of landscape preservation and protection with appropriate structural design. Because of its close distance to Da Nang, Hue city should function as a part of the large tourism industry-oriented region. Therefore, the city should have a clear vision and role among the other tourist destinations, including Da Nang and Hoi An in order to create synergy between these destinations, instead of competition. The regional transportation network should be developed with the HSR system to support such large tourism areas.

4.3.4 Da Nang

The city is located along the coastal area in the center of the country with an international airport in the middle of the city. Such merit of spatial order of the city should be further strengthened as the central gateway on the HSR contributing to the tourism and regional industry. Thus, strong networking with the existing railway station and the airport is mandatory with the HSR station development. There are other tourist destinations and resources, such as four UNESCO heritage sites. Da Nang is considered as the eastern start point of East-West Economic Corridor connecting Laos, Thailand, and Myanmar, and subsequent seaports and industrial zones are developing.

4.3.5 Nha Trang

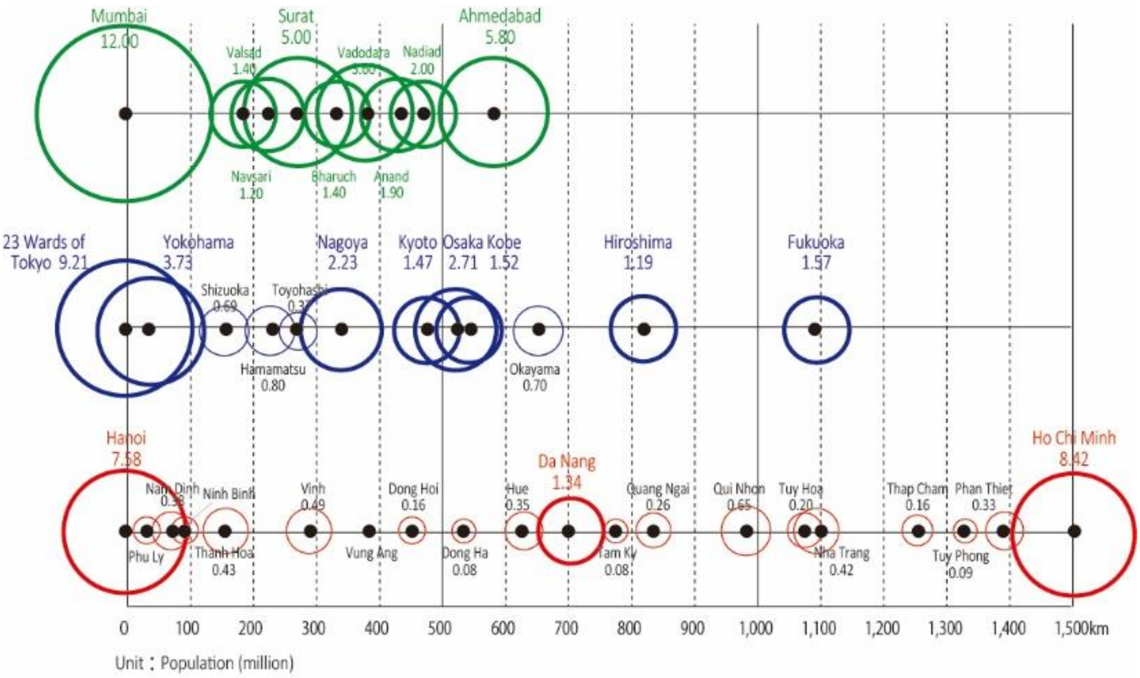
The city of Nha Trang has a strong appeal with its 400 km plus distance from Ho Chi Minh City, and there are a number of industrial and tourism developments ongoing along the coast line in between. As fishery and ship building industries, for instance, are based here, Nha Trang has a large potential for development in this region. The HSR development integrating with the existing railway would be a very important contribution to the industrial and business development in the southern broad region.

4.3.6 Thu Thiem

Ho Chi Minh City is the most populated industrial and business-oriented city in Vietnam. There are daily traffic congestions taking place in many places in the city, so the urban public transportation system and network should be urgently enhanced to improve the situation, and the HSR system needs to be integrated with the nationwide transportation system. The currently proposed station site is located about 7 km east of the city center and Saigon station, this is one of the new urban development areas expanding east nowadays. Therefore, setting the station site at this location considering the eastward growing urban development is appropriate, and the public transportation network between the HSR station and Ho Chi Minh urban center is necessary for effective networking together with future international airport developments.

4.4 Regional Development Concept Plan along the HSR

The utilization of the HSR can be promoted when the mid-sized cities in regional areas are better connected. The figure below shows the urban population along the HSR in India, Japan, and Vietnam. Da Nang is a city with over one million people and is already playing a role as a major regional city, mainly in the tourism sector. It needs to be further strengthened in terms of industrial development as the third largest Vietnamese city.



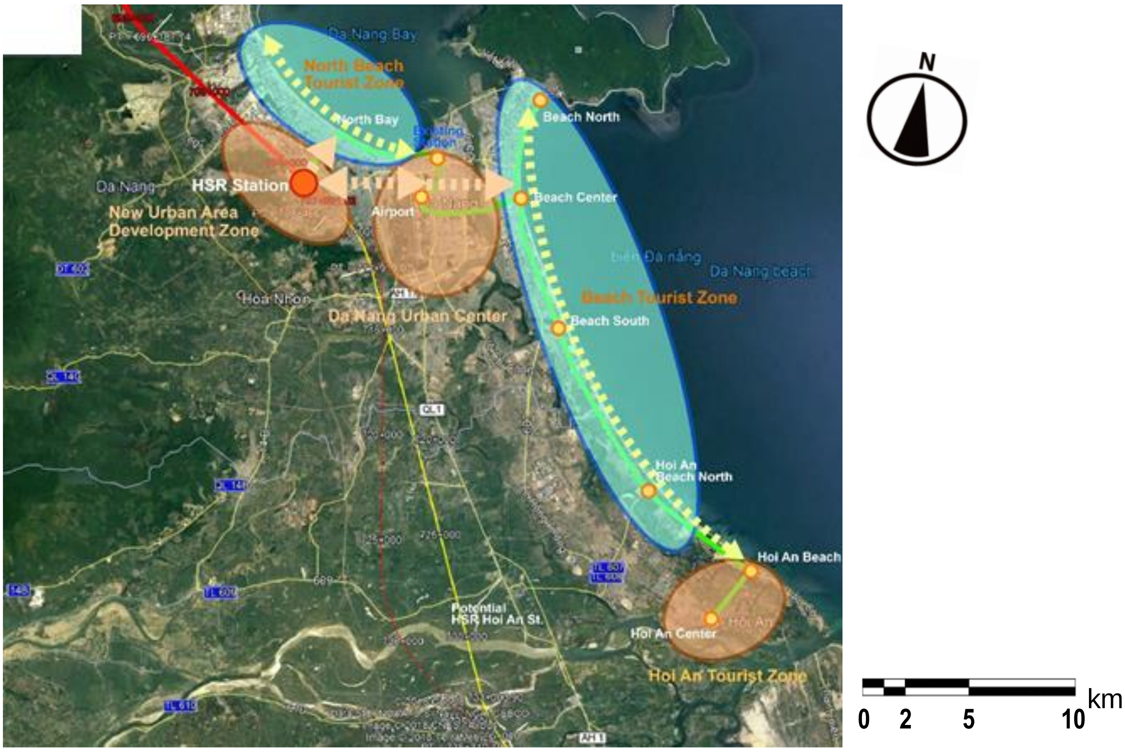
Source: Urban population along HSR in India: Study report of Feasibility Study of HSR in India, JETRO (2004)
Urban population along HSR in Japan: Estimated urban population as of 2018.
Urban population along HSR in Vietnam: the local consultants

Figure S-10: Comparison of Urban Population along High-Speed Rail (HSR) (India, Japan, Vietnam)

Of all the stations along the HSR, Da Nang station, and Nha Trang station – are selected. For each station, TOD concept is outlined as follows.

4.4.1 TOD Concept around Da Nang Station

A network is formed to link the HSR station with other public transport facilities on the city's main roads including Da Nang city bypass. Further, Da Nang city, Hue province and Quang Nam province (in which Hoi An, a city famous for its heritage sites, is situated) are established, respectively, as tourism areas attracting many visitors. However, since there are little cooperation and coordination between these places at present, the maximized use of respective tourism resources is not fully utilized. It is highly beneficial to connect the HSR station, national railway station, and these transport functions to the urban transport network while strengthening the international accessibility. The basic urban transport network system is to establish tourist routes of coastal network lines connecting Hoi An, a route connecting railway stations and airport, and a route connecting major city area functions and attractions; and it is essential to connect all these core routes as one network to achieve smooth transit throughout the city.

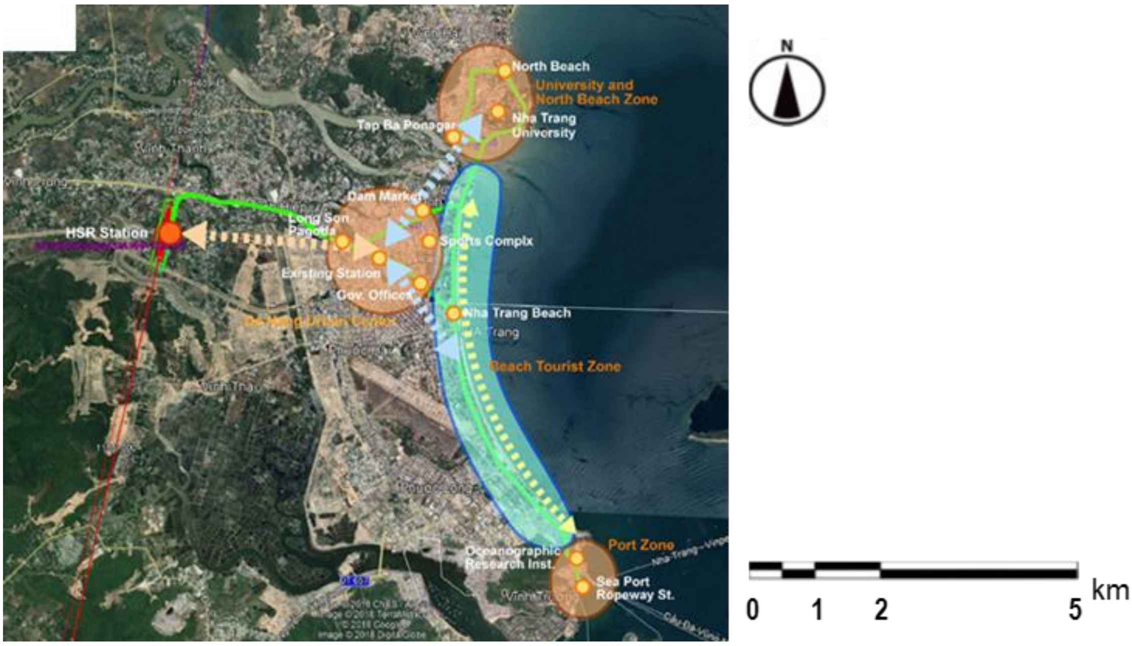


Source: JICA Study Team based on urban development M/P in Da Nang city

Figure S-11: TOD Concept Plan around Da Nang Station

4.4.2 TOD Concept around Nha Trang Station

The city of Nha Trang is one of the largest tourist beach resort destinations in Vietnam. Except for the old airport area, the major part of the urban area is densely developed. Islands popular with tourists also exists, and international cruise ships dock in the bay area. There are well-zoned government and administrative zones, commercial zones, educational and cultural zones, and the university district to the north. These urban nodes may be well developed with an urban transport network system. The long beach tourist zone and north beach zone may be connected with an LRT (Light Rail Transit) type service system to meet the more considerable demand for movement. On the other hand, the transit network connecting the national railway station, bus terminals, central zone, commercial zone, etc. needs to be integrated with the HSR station so that the network system will contribute to wide tourism area development. Currently, the international operating airport is located about 30 km away, and the transport service to the airport may be considered separately from other urban services so that the airport service role could be clearly identified.



Source: JICA Study Team based on Nha Trang city M/P

Figure S-12: TOD Concept Plan Around Nha Trang Station

5. Railway Structures and Facilities

5.1 Civil Structures (Railway, Stations)

5.1.1 Railway

(1) Earthwork (Embankments and Cuts)

Soil improvement is proposed for the places where embankments are constructed on soft ground, which widely spreads to the lowlands of Vietnam. In this project, the adoption of low-cost ground improvement method is a key issue even if the construction period is long, considering past construction experience.

(2) Viaducts and Bridges

Viaducts can be classified into rigid-frame type and PC girder type. Although Japanese style rigid-frame type is economical with the lowest material costs of all viaduct structures, its complicated bar arrangement can pose problems during construction supervision in Vietnam. On the other hand, PC girder type is commonly used in many counties. PC T-girders and PC box girders are applied as typical structures since there is ample experience of PC girder construction works in Vietnam. Long bridges can be classified into concrete bridges, metal truss bridges, and composite girder bridges. Furthermore, concrete bridges can be split into continuous rigid frame girders and continuous girders. Concrete continuous rigid frame girders are typically applied to long bridges as this bridge type can ensure the performance of construction and reduce maintenance costs.

Table S-10: Type of Viaducts and Bridges

Item	Feature	Applicable Location
Viaducts	• There is ample experience of construction works in Vietnam. The construction speed is fast and economical if the same girder type is applied. • To enhance the workability of bridge construction by pre-casting.	Urban areas and suburbs with poor ground conditions
Concrete continuous rigid frame girders	• In order to ensure running safety and riding comfort for HSR rolling stock, strict limits have to be set for girder deflection, unevenness and angular rotation of the track surface and differential displacement. Concrete bridges are more economical than other type of bridges to fulfill the requirement of the set limit for deflection and unevenness. • To increase seismic reinforcement and to reduce construction costs and maintenance costs, continuous rigid frame girders are adopted for large bridges. When adopting continuous rigid frame girders, bearings systems such as rubber bearings and stoppers at column head parts are not needed.	Long Bridges

Source: JICA Study Team

(3) Tunnels

The tunnel cross-section with a double track (which is applied to Japanese HSR) is proposed as a tunnel sectional form. The tunnel buffer construction is proposed in order to reduce the sound blast when a train enters the tunnel at high speed (the air in the tunnel is compressed, and a plosive sound is created at the exit on the opposite side). Finally, the Fore-pile/pole method is proposed as a tunnel auxiliary method since this is the most superior economically from the construction experiences in Vietnam compared with other methods.

(4) Tracks

A ballasted track is applied to earthworks since they can cope with roadbed deformations comparatively easily. A slab track is applied to viaducts, bridges, and tunnels to aim at reducing the maintenance work for tracks.

5.1.2 Station and Station Facilities

(1) Plan and Design of High-speed Railway Stations

- Design with “relieving the passengers’ tension while traveling” in mind
- Enough space and easy to understand arrangement for passengers
- Safety towards earthquakes, weather, fire and easy to use functions even for non-savvy travelers
- Proper arrangement of waiting rooms, cafes/ restaurants, souvenir shops, public agency windows, etc., in consideration of the convenience of passengers and surrounding residents
- Increase profitability from non-fare revenue

(2) The Size of the Station

The style of a station and the building area are decided based on the assumed number of passengers. The following four patterns were set according to the number of passengers.

At stations with many passengers where all the trains stop, two island-type platforms and four lines are required. There are two track types - tracks on the viaduct (elevated structure) and on the ground.

At stations with relatively fewer passengers where only local trains stop, express trains will bypass these local trains stopped at the station. The two side-type platforms and two lines are required. There are also two track types - tracks on the viaduct and that on the ground.

(3) Universal Design

In order to provide comfortable services to all people, the following facilities were planned.

- Space for movement: Automatic ticket checker, Elevator, Escalator, Inclines, Braille block, Double handrail, and stairs Wheelchair lift
- Space for action: Multifunction toilet, Automatic ticket vending machine, Low-rise counter, Interphone, and Breast-feeding room
- Information: Destination guide board, Pictogram, Map, Multilingual Information, and Voice guide
- Accessibility services: Braille information (in bathrooms, on handrails, on fare table), Audio assist, and Service staff
- Safety: Exit displays, Evacuation displays, Emergency call system, Emergency kill switches (for train), and Platform safety barrier

Figure S-13: Slope[6]

Figure S-14: Multi-functional Toilet[7]

Figure S-15: Information Boards[8]

5.2 Electric Power System

5.2.1 Present Status of Vietnamese Power System

In Vietnam, as the Ministry of Industry & Trade (MOIT) has jurisdiction over the field of electricity and energy, the Institute of Energy (IE) under the MOIT has been formulating energy policy plans and power development plans. The Vietnam Power Group (EVN: Vietnam Electricity) owns and manages power generation companies, load dispatching centers, power transmission companies, and power distribution companies for the power system.

As shown in the table below, the ratio of hydroelectric power plants and coal-fired power plants is large. Because of the high ratio of hydroelectric power generation, it is necessary to increase the output of coal-fired power plants in order to secure sufficient power generation during the drought season. As of the end of 2016, total power generation was 42,135 MW.

Table S-11: Generator Capacity by Power Plant Type (December 2016)

Type of Power Plant	Normal Capacity (MW)	Ratio of Power Station (%)
Hydroelectric power	15,857	37.6%
Coal fired power	14,448	34.3%
Oil fired power	1,370	3.3%
Gas fired power	7,502	17.8%
Diesel, Small Hydropower and Renewables	2,418	5.7%
Import	540	1.3%
Total	42,135	100%

Source: EVN Annual report

Regarding Vietnam's electric power system, the power transmission system consists of voltages of 500 kV, 220 kV, and 110 kV. The 500 kV transmission lines are used interconnect between the northern region and the southern region of Vietnam, while the 220 kV transmission lines are used to supply power around the northern area, Ho Chi Minh area and the central area. Vietnam is aiming to upgrade the entire system to 220 kV transmission lines by 2030, according to the National Power Master Plan of Vietnam.

6 https://www.tokyometro.jp/safety/barrierfree/facilities/index.html (Referenced 2019.06.10)
7 https://www.tokyometro.jp/safety/barrierfree/facilities/index.html (Referenced 2019.06.10)
8 https://www.ur-net.go.jp/aboutus/action/ud/ud_08.html (Referenced 2019.06.10)

The facilities of 110 kV or more of the power transmission system are directly grounded neutral systems, making it easy to identify faults in the power system. Also, according to the national electrical regulations, the voltage fluctuation range is specified as ± 5% of the normal voltage.

5.2.2 Future Planning of the Vietnamese Power System

In the 7th National Power Development Plan, achieving sufficient power supply is planned in order to realize the national goal of 7% annual GDP growth rate from 2016 to 2030.

This Development Plan consists of increasing the ratio of thermal power plants in order to stabilize power generation by reducing the ratio of hydro power generation whose output decreases during the drought season to less than 30%. In addition, the total amount of hydro power generators in 2030 (which is the scheduled year for the HSR operation to start) is secured at around 17%, with a power supply configuration that can flexibly respond to load fluctuations.

This Development Plan also aims to strengthen the current 500 kV transmission line and construct a 220 kV linkage line between the north and south. In addition, a transmission line constructed near the high-speed railroad route has been planned.

5.2.3 Power Transmission to HSR

The power supply to the HSR is determined by considering the voltage fluctuation range, the maximum load of the HSR, and the short circuit capacity of the power network system. The value allowable for voltage fluctuation stipulated in the national electrical regulations is ± 5% of the standard voltage during normal operation.

The feeding transformer capacity to supply the maximum load of the HSR is 80 MVA. The reactive power of the maximum load from this feeding transformer capacity is 25 MVAR. Therefore, the required short circuit capacity when suppressing the voltage fluctuation within 5% (which is the voltage fluctuation allowable value of National Power Standard) is 500 MVA. From this short circuit capacity, it is possible to supply from the 110 kV transmission network, but considering the reliability, it is preferable to supply from the 220 kV transmission network (equivalent to the transmission voltage of 275 kV supplied in Japan).

Basically, the power transmission line for the HSR substations is constructed by branches from the existing transmission line. However, if the HSR substation is located near the substation of the electric power system, an exclusive transmission bay to supply power for the HSR shall be newly constructed in the substation.

The cost of the electric power equipment to be supplied from the electric power system to the high-speed rail can be estimated from the following costs:

- The construction cost of the connection transmission line
- The existing equipment remodeling cost for branching the transmission line to construct the connection transmission line
- The cost of exclusive transmission bays in the substations

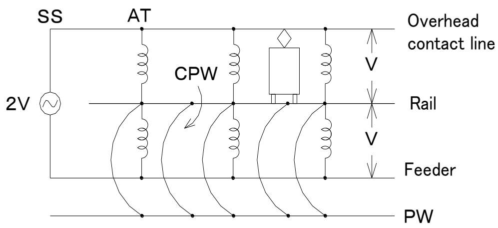
As the plan goes forward, back to the basic planning stage, it is necessary to file an application for power supply of HSR substations to EVN after determining the substation positions of the HSR. At that stage, it is desirable to conduct the study of the detailed power receiving system to connect to HSR substations.

5.3 Power Supply System

5.3.1 Power Supply for HSR

Electricity is supplied to the electric rolling stock through overhead contact lines and rails for operation. The electric system is a single-phase AC 25,000 kV with frequency of 50 Hz. As a feeding system, an Auto Transformer (AT) system is suitable for HSR as it “can have longer distance intervals between substations,” it is “effective in reducing induction to communication lines,” and it “can control the leakage of electrical current from the rails to the ground.” The next table shows the concept of the AT system.

Table S-12: Characteristics of AT Feeding System

Type	Characteristics	Conceptual Drawing
Auto-transformer feeding system	• Suitable for supplying high electricity volume because it can carry feeding voltage (power sent out from a substation) higher than that carried by an overhead contact line • Can have longer distance intervals between substations than other feeding systems • Does not need BT or other sections • Approximately a 10-km interval between two auto-transformers	

Source: JICA Study Team based on the previous study (JICA, 2013)

When a single-phase power supply is generated from a three-phase power system, it is advisable to maintain a balanced electrical current on the three-phase side to prevent failures in the equipment on the three-phase side. For this purpose, the Roof Bridge connection transformer was developed recently to replace the Woodbridge transformer. This new light-weight transformer has been simplified by eliminating the step coil and reducing the coil volume.

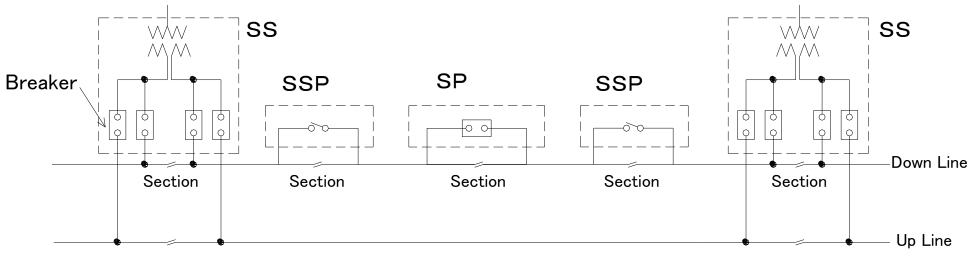
The feeding section interval between the substations is assumed to be approximately 80 km, with 40 km on each side. With the AC feeding system, the adjacent substations have a different phase of power supply. Therefore, a sectioning post (SP) is installed midway between the substations. The study result indicated that 21 substations and 20 sectioning posts will be required. Between a substation and a sectioning post, a sub-sectioning post (SSP) is set up. This makes it possible to isolate the section in the feeding system during maintenance or when an accident occurs. An AT post (ATP) is put in place to provide relief when there is a voltage drop and to mitigate inductive problems triggered by a low-voltage circuit.

Once commercial operations end for the day, power feed from the substations to the main line will also stop so that maintenance can be carried out. The car depots, however, will continue to need power to perform maintenance on the rolling stock and to air-condition the cars to prepare them for early morning operation, even after commercial operation has finished for the day. For this reason, the car depots need a power supply system that is separate from the feeding system to the main line.

There are two ways to supply power to the car depots: by setting up a dedicated substation or by getting dedicated power supply from the nearest substation. The latter is preferred due to cost efficiency.

In long tunnels, sectional disconnectors shall be installed in order to be able to divide the power supply during accidents.

The below figure shows the configuration of a standard feeding circuit.



Source: JICA Study Team based on the previous study (JICA, 2013)

Figure S-16: Configuration of an AC Feeding Circuit

5.3.2 Overhead Contact Line Facility

An overhead contact line supplies power to electric trains from a substation through a pantograph. It consists of; feeding contact line, overhead contact line, protection devices, and various support, etc. Because the overhead contact line must supply stable power to electric trains constantly and is a single-system facility, it must be a very safe and secure facility. The following weather conditions are assumed:

- Temperature: Past temperature data of Vietnam are used as the assumed temperatures for design purposes.
- Wind: The maximum instantaneous wind speed of Vietnam in the past is used as the assumed wind speeds for design purposes.
- Lightning: Lightning measures are planned for all regions of Vietnam.
- Salt damage: Salt damage measures throughout the entire line.

The below table shows the suspension system of the overhead contact line and standard tension.

Table S-13: Types of Overhead Contact Lines and Standard Tension

Section	Suspension system	Kind and Sectional Area		Standard Tension
Main line	Simple catenary suspension system CS simple (tension 4.0 t) (39.2 kN)	Messenger wire	Hard drawn copper wire strands: 150 mm^2	2,000 kgf (19.6 kN)
		Contact wire	CS contact wire: 110 mm^2	2,000 kgf (19.6 kN)
Other Lines	Heavy simple catenary suspension system (tension 2.5 t) (24.5 kN)	Messenger wire	Zinc-coated steel wire strands: 110 mm^2	1,500 kgf (14.7 kN)
		Contact wire	Grooved hard copper contact wire: 170 mm^2	1,000 kgf (9.8 kN)

Source: JICA Study Team based on "Kyushu Shinkansen Construction Reports: Hakata - Shinyatsushiro" (JRTT, 2012)

5.3.3 Electrical Facilities for Lighting

Electrical facilities for lighting differ substantially, depending on whether the electrical facilities are for supplying electricity to load other than HSR rolling stock, or load facilities such as lighting and electrical outlets at station buildings. Electrical facilities refer to the distribution point facilities that receive electricity from utility companies and allocate the electricity to various loads, the distribution line facilities that distribute the allocated electricity to various loads, and lighting facilities (load facilities). Lighting facilities include the facilities inside tunnels, electrical outlet facilities for maintenance use, facilities on station and car depot premises, and building facilities, etc. Building facilities are not included because they are not unique to railway systems.

Since the HSR electrical facilities do not have special systems or mechanical equipment, they shall be configured in the same way as the ones used for conventional electric railways, utility companies, and large power users. However, because it is necessary to coordinate the reliability of power supply with other systems, duplex power supply (double lines) shall be used basically for all facilities directly related to train operation and related load facilities. Furthermore, because the reliability of power supply differs depending on the power-receiving locations, emergency power generators shall be installed to ensure the reliability of power supply.

5.4 Signaling and Communication

5.4.1 Purpose and Function of Railway Signals

The purpose of 'railway signals' is to enable safe the operation of multiple trains mixed on the track. The functions are *Blocking*, *Speed Controlling*, and *Interlocking*.

Blocking dictates that only one train shall occupy a certain section. This is to avoid collisions between trains.

Speed Controlling dictates that trains can operate in a specified direction at speeds less than the specified speed for safety.

Train operators can navigate trains safely according to the signals, i.e. ("green: proceed," "yellow: proceed with caution," "red: stop") or "permissible speed," i.e. (xx km / h or less"). However, if a human error such as misidentification or oversight of the signal aspect occurs, it may cause serious train accidents such as collision or derailment.

Therefore, modern railways are equipped with an automatic train control device, i.e. ATS (Automatic Train Stop device) or ATC (Automatic Train Control device), which has the ability to automatically engage the brakes, decelerate the speed or stop the train when the train's speed exceeds the allowable limit from human error.

Interlocking is the fundamental mechanism that dictates the other trains shall never enter on the same route where a train is on or in the direction it is heading.

5.4.2 Study on the Signaling System in Vietnam HSR

(1) The Signaling System on the Tokaido Shinkansen

The full-stop braking distance from the maximum speed of 210 km/h was over 3 km, which greatly exceeds the driver's ability to see. This means the "speed control" by human's attention alone is impossible to secure the safety of high-speed trains.

For this reason, on the Tokaido Shinkansen, "Blocking" and "Interlocking" functions from conventional railway were adopted, but for "Speed Controlling," ATC was introduced which automatically lowers the train speed following the signal transmitted from the ground.

For further speeding-up/ high-density operations, the ATC of the Tokaido Shinkansen was also improved from a multi-stage brake control based on the original analog speed signal, to a one-stage brake control which automatically applies the brakes based on digital signals so that the train can stop exactly at the required point. This brake control has the advantage of shortening braking distances and increasing ride comfort.

(2) VHSR-ATC (Vietnam HSR-ATC)

When ATC control information is digitally transmitted via track circuit, it is necessary to change the modulation frequency to the voice band (600 Hz to 1,200 Hz) to meet the transmission capacity, and it is also necessary to reduce the length of one track circuit to about 1 km or less, suppress the current leakage from the line, and realize stable information transmission. Therefore, as the distance between stations increases, the installation cost of the inter-station track circuit equipment increases. Moreover, the installation and maintenance costs will increase to realize the two-way operation on a double track section.

The concept of VHSR-ATC proposed is as follows. The function of the ground device determines the target distance from the received "train position" by track circuit to "stop/deceleration target point" and transmits this "distance to stop / deceleration target point" to the onboard device in real time. The function of the onboard device transmits train-ID with position to the ground device in real time, receives "distance to stop / deceleration target point" in real time and creates a "brake curve profile" that matches the received "distance to the stop/deceleration target point." The current position and speed of the train, line information of the onboard database is calculated to perform the necessary one-stage brake control.

Compared with the current DS-ATC of the ATC control signal transmission system by the track circuit, VHSR-ATC improves the safety and efficiency of train control, realizes the two-way operation on a double track section and reduces the burden of construction and maintenance of signal equipment. This system is undergoing final testing on the Shinkansen line in Japan and would be completed by the time of the Vietnamese HSR.

5.5 Rolling Stock and Depot

5.5.1 Rolling Stock

To maintain the safe operation of the high-speed train, dedicated standard gauge tracks should be introduced. Therefore, using the conventional line should not be considered. For stabilized high-speed train operation (more than 300 km/h) a distributed traction system such as EMU should be adopted. The advantage of EMU is not only high power and low coefficient of adhesion in power, but also regenerative brake can share brake force without pneumatic friction brake. Basic specification is based on the E5 series of the Tohoku Shinkansen.

For optimal compatibility between large transportation flow and low initial cost, a wide car body (5 seats per row) can be operated at more than 300 km/h on a narrow track bed (4.3 m distance between track centers) and small cross-section tunnel (64 m^2). These core features are proven in the design of the Japanese Shinkansen.

Table S-14: Basic Specification of Rolling Stock for VHSR

Item	Specification
Track gauge	1,435 mm
Power supply	AC 25 kV 50 Hz
Maximum speed	350 km/h (design), 320 km/h (operation)
Train configuration	10 cars (8M2T), 16 cars (14M2T) in future
Passenger capacity	10 cars: 740 (Executive C. 55, Economy C. 685) 16 cars: 1,220 (Executive C. 122, Economy C. 1,098)
Total weight (unloaded)	10 cars: Approx. 460 t, 16 cars: Approx. 740 t
Maximum axle load	14 t (100% passenger load)
Length (middle car)	25,000 mm
Maximum width	3,350 mm
Maximum height	3,650 mm
Body structure type	Aluminum alloy double-skin extruded structure (Airtight structure body)
Bogie type	Bolster-less type
Control system	Converter-Inverter VVVF control system (IGBT 3 level PWM)
Traction motor	Induction motor 300 kW
Pantograph	Single arm & low noise type 10 cars: use 1 of 2 units, 16 cars: use 2 of 4 units
Brake system	Electric command system with regenerative brake
Safety system	Digital ATC with onboard brake control
Train radio	Space wave & LCX (digital)

Source: JICA Study Team

5.5.2 Depot

(1) Depot Installation

In this study, five depots are set for storage and maintenance vehicles (Wheel turning, Vehicle Washing, Trip inspection, Regular inspection, General inspection). These five depots are set considering the phasing and the distance between depots. The overview of each depot is shown in the below table. Furthermore, workshops are set up at each of the two sections that are operated from the earlier phase.

The number of storage lines for each depot is set from the operation plan of 2030, 2040, 2050 and 2070. The number of inspection lines and the space required for various buildings is set referring to the Japanese Shinkansen.

(2) Maintenance Base

In order to maintain the track, Maintenance bases are set at intervals of approximately 50 km. The total number of maintenance bases is 42. Five of them are in depots; the number of single maintenance bases is 37.

Maintenance is done at a limited time outside the hours of operation. When the maintenance depot interval becomes longer, it takes longer time for a round trip, and work efficiency decreases. For this reason, in Japan, the maintenance depot interval is 30 to 50 km as the standard.

5.6 Estimated Construction Costs

5.6.1 Methodology of Cost Estimation

In determining the cost of civil engineering works, the actual and/or calculated unit costs applied for past, on-going and upcoming Vietnamese projects are used for reference (From the local consultants / others). For construction works with no history in Vietnam such as electrification, high speed turn-outs, train control system, cars and other sophisticated facilities, Japanese experience in HSR construction are used as a basis for determining the unit cost.

5.6.2 Information Used for Civil Engineering Unit Price

Cost estimation is carried out using the actual project construction cost for embankment, cutting, viaduct, culvert, bridge, tunnel (road tunnel), and related works in Vietnam.

5.6.3 Exchange Rate

The exchange rate used to calculate the construction costs in Vietnam is based on the rates recorded on October 31, 2018 as shown below.

1 USD = 109.31 JPY
1 USD = 22,726 VND
1 VND = 0.00481 JPY

5.6.4 Estimated Construction Cost: Removed

6. Railway Operation and Maintenance

6.1 Train Operation Plan

Two train operation plans for both cases were prepared. Two-step Case divides the entire section into three construction sections to start operation in two stages. Five-step Case divides into 5 sections to start operation in 5 stages. The below table shows the proposed train operation plan.

Table S-15: Train Operation Plan

Case	Opening	Section			Cars /train-set	Trains /day /direction	Number of Train-set
Two-step	2030	Ngoc Hoi	–	Vinh	10	36	14
		Nha Trang	–	Thu Thiem	10	36	16
	2040	Ngoc Hoi	–	Vinh	16	76	83
		Vinh	–	Da Nang	16	72	
		Da Nang	–	Nha Trang	16	72	
		Nha Trang	–	Thu Thiem	16	78	
	2050	Ngoc Hoi	–	Vinh	16	86	96
		Vinh	–	Da Nang	16	78	
		Da Nang	–	Nha Trang	16	78	
		Nha Trang	–	Thu Thiem	16	90	
Five-step	2030	Long Thanh	–	Thu Thiem	5	20	3
	2040	Ngoc Hoi	–	Vinh	10	46	14
		Long Thanh	–	Thu Thiem	5	28	3
	2050	Ngoc Hoi	–	Vinh	10	60	19
		Nha Trang	–	Thu Thiem	10	50	19
	2060	Ngoc Hoi	–	Vinh	10	68	22
		Da Nang	–	Nha Trang	10	34	47
		Nha Trang	–	Thu Thiem	10	82	
	2070	Ngoc Hoi	–	Thu Thiem	16	106	107

Remark: No cleaning work for turn-back trains between Long Thanh-Thu Thiem in 2030 and 2040 for Five-step Case. The number of train-sets includes extra trains for periods of high demand and emergencies, but excludes inspection purposes.
Source: JICA Study Team

The maximum train speed is 320 km/h and the operating hours was set to 6:00-24:00. The time required between Ngoc Hoi – Thu Thiem is 7 hours and 15 minutes for the local train, and 5 hours and 20 minutes for the express train (including the stoppage time and margin time on the operation plan such as overtaking).

The number of one-way trains is set at least one per hour and corresponds to the passenger volume. The average boarding ratio is assumed at 70%. The number of vehicles in one train-set is assumed to be 5 cars, 10 cars and 16 cars considering demand, characteristic of vehicles and period of use. The number of trains was calculated for each section separated by stations, Ngoc Hoi, Vinh, Da Nang, Nha Trang, and Thu Thiem where the train yards are set. The trains were planned to run between Hanoi and Thu Thiem thorough as far as possible. Trains stop two minutes for passengers getting on and off at intermediate stations. At reversing stations, it takes in principle more than 40 minutes for waiting for passengers boarding and alighting and vehicle maintenance such as cleaning.

6.2 Maintenance

6.2.1 Outline of Shinkansen Maintenance

In order to inspect the condition of the track and electric circuit, an inspection train runs about once every ten days on the whole line. The inspection data is processed by the Shinkansen Management Information System and used towards maintenance work for improving ride comfort, stable current collection, prevention of signal troubles, etc.

The maintenance work of the Shinkansen begins after the normal hours of operation and finishes before the operation of the first train the next morning, which is different from the conventional line where line maintenance is done during business hours.

The transportation commander is responsible for determining the time of the maintenance work. The facility commander controls the maintenance works. Specifically, the commander is responsible for instructing the setting of maintenance work content and work time, approval of the start/end of work, as well as handling of abnormal situations. Before returning to the operation time after the maintenance work is completed, a confirmation car is operated to check that there are no abnormalities with the railway track, etc.

Source: JR Tokai[9]

Source: Niigata Transys KK[10]

Figure S-17: Inspection Train and Confirmation Car

Maintenance technology has improved over time, below are examples.

Table S-16: Improvement of Component and Material

Field	Item
Car	Aluminum body, AC induction motor, VVVF inverter, Auxiliary power supply unit, High-frequency induction hardening axle, Sealed bearing, Unit brake, Regenerative brake, Abrasion-resistant brake material, Carbon-based contact strip, a High voltage bus bar (reduced number of pantographs)
Track	Long rail, Slab track, Head hardened rail, Elastic sleeper on ballast track, Synthetic sleeper
Power	High tension overhead wire structure, Wear-proof trolley wire

Source: R&D on Railway Maintenance - Present and Future, Railway Technical Research Institute

The future direction of maintenance includes the advancement of preventive maintenance, elucidation of boundary issues such as rail-wheel and automation of inspection and labor-saving methodologies.

[9] https://railway.jr-central.co.jp/train/work/detail_04_01/index.html (Referenced 2019.06.10)
[10] http://www.niigata-transys.com/products/photo02.html (Referenced 2019.06.10)

When planning the maintenance system in the Vietnam HSR, it is important to recognize that the conventional railway and HSR are entirely different systems. The first step is to adopt the maintenance system that is being carried out on the Shinkansen into the Vietnam HSR. Then, make improvements while observing the situations onsite and studying examples in other countries.

6.2.2 Shinkansen Track Maintenance

For the Tokaido Shinkansen, the ballast track was fully adopted. The reason was that at the time, alternative track types were not put into practical use, and the construction cost was low.

After the start of operation, it was found that track destruction rapidly progressed by operation of the high-speed train, and the development and practical application of the slab track type were advanced rapidly as the new track structure. Since 1960, the adoption of the slab track became the standard. On the other hand, for sections where application of the slab track is difficult, an improved ballast trajectory has been applied.

The characteristics of the improved ballast track are as follows (comparing the previous ballast type with the improved ballast type).

Table S-17: Comparison of Ballast Track

<table>
<tr><th rowspan="2">Item</th><th colspan="3">Previous type</th><th colspan="3">Improved type</th><th rowspan="2">Note</th></tr>
<tr><th>Soil structure</th><th>Tunnel</th><th>Viaduct</th><th>Soil structure</th><th>Tunnel</th><th>Viaduct</th></tr>
<tr><td>Rail</td><td colspan="3">60 kg</td><td colspan="3">60 kg</td><td></td></tr>
<tr><td>Tie pad</td><td colspan="3">90 t/cm</td><td colspan="3">60 t/cm</td><td>Reduction of spring constant</td></tr>
<tr><td>Ballast mat</td><td>-</td><td>-</td><td>-</td><td>-</td><td>Install</td><td>Install</td><td></td></tr>
<tr><td>PC sleeper</td><td colspan="3">3T or 4T
(W = 280 mm, D = 190 mm)</td><td colspan="3">3H
(W = 310 mm, D = 220 mm)</td><td>To increase elasticity</td></tr>
<tr><td>Ballast thickness (mm)</td><td>300</td><td>250</td><td>200</td><td>300</td><td>250</td><td>200</td><td></td></tr>
</table>

Source: Track Structure of Shinkansen (Japan Railway Civil Engineering Association, 1973)

The feature of the improved ballast track was to make the entire track structure soft and to suppress the unevenness of the rail surface. These measures support the reduction of the large wheel load along with the reduction of unsuspended mass. The following is the list of improvements.

1. Reduction of rail support spring constant
   - Decrease in the spring constant of tie pads
   - Increase in the elasticity of sleepers
   - Inserts a rubber plate between sleepers and road floor
   - Applies moderate elasticity to the trackbed
     (Prevention of ballast deterioration by controlling the size and quality of the ballast)

2. Suppression of short wavelength track deviation such as unevenness of rail surface roughness
   - Improvement of completion accuracy of welded seams
   - Improvement of completion accuracy (tolerance) during rail production

The following table shows the track structure of the Tohoku Shinkansen.

Table S-18: Track Structure and Applied Line of the Tohoku Shinkansen (Tokyo – Morioka)

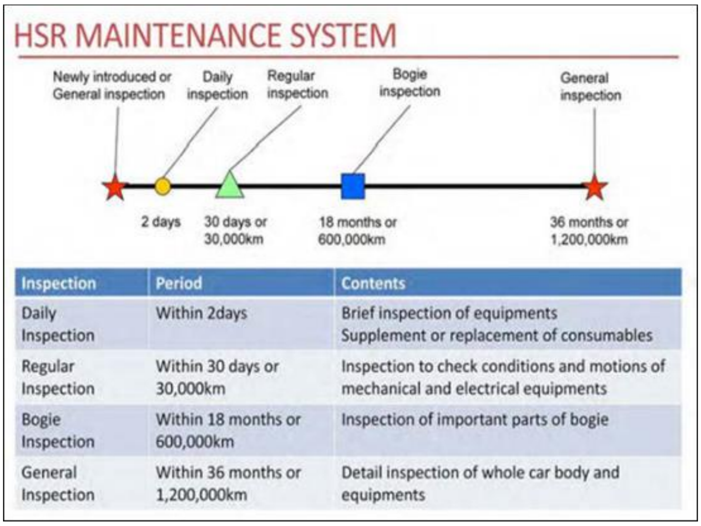
		Mainline			Other line
		Main track	Passing track	Dead-heading	Arrival/Departure track
Rail		60 kg Long (R>800 m) Standard (R<800 m)	60 kg Long rail or Standard rail		More than 50 kg
Slab /Sleeper		Slab or PC3H 43/25 m	Slab or PC3T or PC4T 42/25 m		RC39+W1 /25 m
Rail joint		Expansion joint (R≥1,000 m) Glued-insulated joint (Standard rail section or Supported joint)	Simple expansion joint or Glued-insulated joint or Supported joint		Supported joint
Rail fastening	Slab	Direct type 4 or type 5			
	Ballast	60 kg high-speed type 60G large scale sleeper	102 Improved type 60G for large-scale sleeper		RC103 Improved type F type, 50H for large-scale sleeper
Ballast depth	Earthwork	Crushed stone more than 300 mm		Crushed stone more than 200 mm	
	Tunnel	more than 250 mm			
	Viaduct	more than 200 mm			
Ballast mat		Ballast mat for tunnel or viaduct type		-	

Source: Track Construction of Tohoku Shinkansen: Tokyo – Morioka, Railway Track, (Japan Railway Civil Engineering Association, 1974)

6.2.3 Rolling Stock

(1) Type and Period of Inspections

Inspections of rolling stock are classified into daily inspections, regular inspections, bogie inspections, and general inspections. More information is shown in the following figure. The daily inspection is conducted at a depot, and regular, bogie, and general inspections are carried out at a workshop.



Source: The previous study (JICA, 2013)

Figure S-18: HSR Maintenance System

(2) Flow of Inspections

The inspection flows are shown in the table below.

Table S-19: Flow of Inspections

Kind of Inspection	Flow of Inspection	Time Required
Daily	Entering daily inspection track (Self-running) → Cut catenary disconnecting switch → Unlock of door of roof-top inspection stand → Inspection of equipment on roof → Confirmation that there is no worker on roof-top inspection stand → Lock of door of roof-top inspection stand → Inspection of indoor equipment/underfloor equipment → Completion of daily inspection → Switch on catenary disconnecting switch → Exit daily inspection track (Self-running)	1 hour
Regular	Entering regular inspection track (Self-running) → Cut catenary disconnecting switch → Unlock of door of roof-top inspection stand → Inspection of equipment on roof → Inspection of indoor equipment/underfloor equipment → Confirmation that there is no worker on roof-top inspection stand → Switch on catenary disconnecting switch → Confirmation of equipment operation → Completion of regular inspection → Exit daily inspection track (Self-running)	Half a day
Bogie	Entering bogie inspection transfer track → Entering bogie inspection track → Lifting up car body → Detachment of car body and bogie → Unlock car body load lock → Lifting of car body → Move bogie to unrepaired bogie storage track → Move repaired bogie from repaired bogie storage track → Adjustment of location of bogie → Body lowering → Lock car body load lock → Remove jack from car body → Move to bogie inspection transfer track → Test and adjustment as onetrain set → Running test in workshop → Completion of bogie inspection and deadheading	Half a day
General	Entering general inspection transfer track → Inspection upon entering → Move to general inspection shop → Unlock car body load lock → Detachment of car body and bogie → Move to car body shop → Removal and repair of parts → Move to car body washing shop → Cleaning of inside of car body → Masking for car body coating first color → Painting for car body painting first color → Drying of paint → Masking for car body coating second color → Painting for car body painting second color → Drying of paint → Move to general inspection track → Mounting car body parts → Put the car body on bogie → Move to general inspection transfer track → Unit test → Running test in workshop → Running test in main line and hand over	15 days

Source: JICA Study Team

(3) Depot and Workshop

Depots are set up in five places in Hanoi, Binh, Nha Trang, Da Nang, Ho Chi Minh City, and they conduct survey inspections. A workshop is constructed in two places, Hanoi and Ho Chi Minh City. The number of inspections at the workshop in 2050 is as follows.

Table S-20: Number of Inspections at Workshop

	Daily	Regular	Bogie	General
Number of inspections	7,300	1,914	85	47

Source: JICA Study Team

The layout of the workshop is shown in Figure 5.15. Other major facilities include two traversers, track and catenary inspection car shed, wheel grinding shop, business vehicle inspection shop (new car restoration shop), power room, material storehouse, sewage treatment facility, etc.

6.3 Operation and Management Organization

The required number of employees for operation is shown in the table below.

Table S-21: Personnel Component for HSR in Two-step Case

Organization		2030	2040	2050
Head Office		173	173	173
Hanoi Branch Office	Control division	194	194	194
	Worksite offices	1,944	6,043	6,339
	Total	2,138	6,237	6,533
Ho Chi Minh Branch Office	Control division	194	194	194
	Worksite offices	2,325	6,157	6,385
	Total	2,519	6,351	6,579
Total		4,830	12,761	13,285

Source: JICA Study Team

The worksite offices consist of stations, driver/conductor-depots, rolling stock inspection bases, rolling stock workshops, track maintenance-depots, power supply-depots, signal/ telecommunication-depots and material centers. The required number of worksite employees are shown in the table below.

Table S-22: Number of Worksite Employees in Two-step Case

Organization		Number of employees		
		2030	2040	2050
Hanoi Branch Office	Station	357	942	1,029
	Driver/ Conductor - depot	131	654	723
	Rolling Stock Inspection Base	38	158	196
	Rolling Stock Workshop	318	1,150	1,252
	Track Maintenance - depot	429	1,299	1,299
	Power Supply - depot	337	990	990
	Signal/ Telecommunication - depot	284	750	750
	Material Center	50	100	100
	Total	1,944	6,043	6,339

Organization		Number of employees		
		2030	2040	2050
Ho Chi Minh Branch Office	Station	371	789	868
	Driver/ Conductor - depot	156	687	765
	Rolling Stock Inspection Base	38	118	156
	Rolling Stock Workshop	318	1,150	1,252
	Track Maintenance - depot	595	1,411	1,411
	Power Supply - depot	435	1,046	1,046
	Signal/ Telecommunication - depot	362	792	792
	Material Center	50	95	95
	Total	2,325	6,088	6,385
Total	Station	728	1,731	1,897
	Driver/ Conductor - depot	287	1,341	1,488
	Rolling Stock Inspection Base	76	276	352
	Rolling Stock Workshop	636	2,300	2,504
	Track Maintenance - depot	1,024	2,710	2,710
	Power Supply - depot	772	2,036	2,036
	Signal/ Telecommunication - depot	646	1,542	1,542
	Material Center	100	195	195
	Total	4,269	12,131	12,724

Source: JICA Study Team

The personnel component and the required number of worksite employees for HSR in Five-step Case are shown in the table below.

Table S-23: Personnel Component for HSR in Five-step Case

	2030	2040	2050	2060	2070
Head Office	20	90	173	173	173
Branch Offices	30	224	388	388	388
Worksite Offices	330	2,350	5,005	8,123	13,550
Total	380	2,664	5,566	8,684	14,111
Station	112	484	940	1,354	1,985
Conductor/Driver - depot	13	185	432	763	1,911
Rolling Stock Inspection Base	32	70	208	334	725
Rolling Stock Workshop	73	391	880	1,284	2,446
Track Maintenance - depot	40	469	1,024	1,783	2,710
Power Supply - depot	30	382	775	1,342	2,036
Signal/ Telecommunication - depot	25	319	646	1,118	1,542
Material	5	50	100	145	195
	330	2,350	5,005	8,123	13,550

Source: JICA Study Team

6.4 Estimated Operation and Maintenance Cost: Removed

7. Social Infrastructure

7.1 Laws and Regulations

7.1.1 Railway Law in Vietnam

In June 2017, the updated Railway Law (Law 03/2017/L-CTN) was passed by the National Assembly in Vietnam, stipulating railway infrastructure planning, investment, construction, protection, maintenance and development, as well as railway industries and businesses. Compared to the Railway Law enacted in 2005, new provisions have been added, including Chapter 8 on high-speed railways. In the updated Railway Law, the HSR is defined as "a type of national railways with a designed speed from 200 km/hour and more, a gauge width of 1,435 mm, double track, and electrified railways".

According to Chapter 8 on HSR, such infrastructure shall efficiently connect large urban areas, economic centers, key economic regions and other transport modes. It also states that the State will play the leading role in the construction, investment, management, maintenance, and operation of the HSR and the land for construction shall be approved by competent government agencies according to the construction master plan.

In regards to the HSR infrastructure, it stipulates that it shall be stable and sustainable and shall meet the technical requirements on safety, environment, fire, and explosion prevention corresponding to the invested HSR. The law also stipulates that the power supply system shall be centrally and stably controlled and monitored and shall be capable of preventing interruption of train operation.

7.1.2 Efforts and Procedures Required for the Introduction of HSR from Legal Standpoint

HSR is quite different from conventional lines. The first step forward was the addition of the chapter on HSR in the Vietnamese Railway Law. As a future initiative, the following items are required.

(1) Government of Vietnam

- Law: HSR has been defined in the Railway Law
- Decree: As supplement to the Railway Law, Decree for the procedures for actual implementation and operation is recommended to be formulated. The Nationwide Shinkansen Network Construction Law in Japan can be referred.
- Circular: It is recommended to stipulate that MOT's control on safety, inspection and certification of the new line, certification of new rolling stock, and certification of operator license for HSR. It is also recommended to include technical specifications announced to the railway organization and act as a performance standard that would enforce the introduction of new technology.

(2) Railway Organization

The Vietnamese Government must formulate an institutional system (regulator, executing agency, HSR operator) for the implementation of the HSR. At the organizational level, standards and manuals need to be formulated as follows:

- Standards: It is recommended to include technical standards for construction, operation and maintenance. It is assumed to be prepared by the Railway Organization according to the Railway Law and regulations mentioned above. It shall be submitted to MOT for approval.

- Manuals: It is recommended to include the specific procedures for construction, operation and maintenance. It is assumed to be prepared by the Railway Organization according to the regulations and internal standards.

7.2 Development of the Railway Industry and Supporting Sectors

The development of the railway industry is necessary to construct and operate railways. The industrial development also encourages the growth of various supporting industries, which further promotes medium and long term economic growth of the country. Railways require an integrated system consisting of vehicles, structures, power supply, and signals and communications. Each technology also requires high-standard knowledge of civil engineering, electricity, and machinery, etc. Therefore, the development of the railway industry helps to improve the industrial power of the whole country, and the spillover effect can be expected to supporting industries (construction, manufacturing, transport and communications, energy, and service).

7.2.1 Development and Opportunities in Southeast Asia

The Vietnamese railway system is a growing industry with ongoing and upcoming railway upgrading projects, but its absolute market size remains small compared with those of China, India, and some of the other ASEAN countries. To overcome this limitation in the long-term, the country must explore strategies for regional cooperation, looking beyond its borders to export markets.

There are several issues in developing HSR networks covering multiple countries; differences in construction standards and technology levels, competition among contractors, funding and environmental issues, and legal systems. However, even considering these issues, the railway network development in Southeast Asia is a great opportunity for Vietnam to expand its economy, in cooperation with neighboring countries, in particular, ASEAN member countries.

The economies of neighboring Southeast Asian countries are growing steadily, and commerce frameworks such as AFTA, CPTPP, and RCEP have been steadily developed. ASEAN will carry out regional trade based on mutually beneficial role sharing, taking advantage of the new economic opportunities provided by these policies. The Vietnamese railway industry is recommended to extend its strengths while collaborating with its surrounding countries.

7.2.2 Capacity Building

For boosting Vietnam's international competitiveness, it is necessary to improve its expertise beyond simple assembly and repetitive work. That requires a system supporting and promoting technology transfer and practical training through a systematic curriculum. It takes over several decades to acquire advanced technology.

Taking the production of railway vehicles as an example, it is realistic to start with assembly by knockdown and gradually increase the number of parts manufactured in Vietnam while accumulating know-how.

In order to transfer technology from developed countries, it is preferable to establish a joint venture that produces parts and export products to ASEAN countries as well as domestic use. The following table visually shows step-by-step technical enhancement.

Table S-24: Technical Transfer in Phases

Rolling Stock Assembly	**Interior Parts Manufacturing**	**Electrical Parts Manufacturing**	**Machinery Parts Manufacturing**
• Establish facilities in the country for assembly and dismantling • Study the parts for domestic manufacturing • Establish manufacturing companies (e.g. JV)	• Start with technically simple parts • Pay attention to safety regulations and different international standards	• Start with simple, non-essential parts • Set up horizontal or vertical division of labor with other ASEAN countries • Gradually acquire design technology from international experts	• Start with simple, non-essential parts • Focus on materials produced/obtained locally • Ensure government policies encourage technical training programs

Source: JICA Study Team

8. Preliminary Economic Analysis: Removed

9. Project Scheme Options

With regards to project scheme and project executing entity, three options (see below) could be considered based on experiences of foreign countries and observation of the current conditions in Vietnam in terms of railroad operation and legal framework of public-private partnerships (PPPs).

- VNR becomes a project entity, develops and operates the project.
- Private enterprises establish a project company, which develops and operates the project.
- VNR and private enterprises establish a project company, which develops and operates the project.

The advantages of involvement of private enterprises are:

- It may help the government to decrease its (direct) expenditure
- It may realize cost reduction and service improvement by using technologies and know-how of private enterprises.
- Reduction of project cost may shorten the project construction period, which will enable earlier commencement of service provision.

On the other hand, there are the following challenges with regards to the involvement of private enterprises:

- Private companies may not participate due to ridership risk, land acquisition risk, and profitability, etc. which most private enterprises cannot control.
- There are no private enterprises who have experience of running a HSR business in Vietnam.

As to the third point mentioned above, in particular, it is considered essential to receive cooperation and/or support from foreign entities who have experience of running a high speed rail business, to supplement the lack of technology and experience of Vietnamese enterprises and organizations.

Whichever option ultimately gets decided, it is essential to go through a public procurement process and ensure competition and transparency if the government selects any private companies to be involved in the project.

10. Financing Options

As mentioned in the previous chapter, three options could be considered as the project scheme, and the funding sources are broadly classified into government source and private source. The former can be further classified into the government's own revenue such as tax and domestic borrowing, and foreign borrowing including ODA.

Among these, regarding the government's own budget, although the amount has been increasing due to the country's economic growth, the head room for this project investment is quite tight in consideration of other existing investment programs. Also, regarding foreign borrowing, the debt amount is almost reaching the limit of 65%, which is determined by the national assembly; it means the government cannot easily increase its foreign borrowing under the status quo. With this situation, it is understandable that government has high hopes for the mobilization of private funds. However, such an optimism should be avoided because it is not easy. The reason is that there are many hurdles to be overcome to adopt PPP or attraction of private investment as discussed in the previous chapter, on top of the fact that the investment amount is almost equivalent to the government's annual expenditure.

Because of these reasons, it is difficult to conclude a clear answer to this question under this study framework. However, one clear thing is that it is unrealistic to depend on the private sector to shoulder much of the investment cost. Therefore, obviously the government should secure the budget for construction from foreign borrowing including ODA and/or internal sources. It is recommended that the government shall take an approach to seek mobilization of private funds (or mitigate the government expenditure) under the precondition that the primary source of the investment cost should be the government. Lastly, it is worth pointing out that the fiscal sustainability and affordability are the two key factors to be considered, in addition to the technical aspects, in determining the construction schedule.

11. Preliminary Financial Analysis: Removed

12. Operation and Effect Indicators

12.1 Operation Indicators

Proposed operation indicators, which quantitatively show the operation status of the Project, are shown in Table S-25. It is recommended for the operator of the Project to monitor the indicators annually and report the monitoring results to the Ministry of Transport, relevant development partners, investors and lending institutes with annual reports, as well as to publicize the status to the public. The operator is encouraged to advertise the high reliability of the high speed rail service and to encourage passengers to shift from other transport modes for increased ridership of the service. Targets of the operation indicators are shown in Table S-26.

Table S-25: Proposed Operation Indicators

Indicator	Definition	Remarks
1. Transportation Volume	Annual passenger × kilometer (million)	As basic indicators, operators are encouraged to monitor and report the results to the Ministry of Transport, relevant Development Partners, Investors and Lending Institutes as well as to be published to the public.
2. Number of Train Services	Number of annual train services (one-way trips/year)	
3. Operation Rate of Rolling Stock	Number of running cars × day/Number of cars owned × Operation days of the year (%)	
4. Operation Reliability	Number of trains departing the origin stations within 15 minutes of the scheduled time / Number trans scheduled for the services (%)	* Delays/suspensions of force majeure are not counted. * Promotion of large number of passengers by appealing high reliability of the high speed rail service

Source: JICA Study Team

Table S-26: Targets of Operation Indicators

Indicator		Target (Two-step Case)			
1. Transportation Volume (Annual passenger × kilometer in millions)		**2030**		**2040**	**2050**
		7,167		67,466	72,755
2. Number of annual train services (round-trips/year)	Section	**Ngoc Hoi - Vinh**	**Vinh - Da Nang**	**Da Nang - Nha Trang**	**Nha Trang - Thu Thiem**
	2030	26,280	---	---	26,280
	2040	55,480	52,560	52,560	56,940
	2050	62,780	56,940	56,940	65,700
3. Operation Rate of Rolling Stock (%)		**2030**		**2040**	**2050**
		89.3%		92.3%	92.5%
4. Operation Reliability (%) *		98%			

Indicator		Target (Five-step Case)				
1. Transportation Volume (Annual passenger × kilometer in millions)		**2030**	**2040**	**2050**	**2060**	**2070**
		138	2,244	7,015	14,800	82,892
2. Number of annual train services (round-trips/year)	Section	**Ngoc Hoi - Vinh**	**Vinh - Da Nang**	**Da Nang - Nha Trang**	**Nha Trang - Thu Thiem**	**Long Thanh - Thu Thiem**
	2030	---	---	---	---	14,600
	2040	33,580	---	---	---	20,440
	2050	43,800	---	---	36,500	---
	2060	49,640	---	24,820	59,860	---
	2070	77,380	77,380	77,380	77,380	---
3. Operation Rate of Rolling Stock (%)		**2030**	**2040**	**2050**	**2060**	**2070**
		73.3%	85.9%	91.6%	90.7%	91.8%
4. Operation Reliability (%) *		98%				

Note) *: Referring to example of Taiwan High Speed Rail (Annual Reports 2007-2016, Route length; 345 km - 22% of the North-South High Speed Rail Project in Vietnam).
Taiwan High Speed Rail has achieved higher than 99% rate of trains departing the origin stations within five minutes, was within ten minutes for 2007, of the scheduled time to total trains scheduled for the services.
Source: JICA Study Team

12.2 Effect Indicators

Proposed as effect indicators, which quantitatively show effects caused by the Project implementation, are shown in Table S-27. Same as operation indicators, the operator of the Project is recommended to monitor the indicators and report the monitoring results to the Ministry of Transport, relevant development partners, investors, lending institutes and the public with annual reports. Targets of the effect indicators are listed in Table S-28.

Table S-27: Proposed Effect Indicators

Indicator	Definition	Remarks
5. Transportation Volume	Annual passenger × kilometer (million passenger-km)	As a basic indicator, operators are encouraged to monitor and report the results to the Ministry of Transport, Development Partners, Investors and Lending Institutes as we as publish to the public
6. Travel times of specific sections	Average travel times of sections among specific stations (hours : minutes : seconds)	

Source: JICA Study Team

Table S-28: Targets of Effect Indicators

Indicator	Target (Two-step Case)					
5. Transportation Volume (Annual passenger × kilometer in millions)	2030		2040		2050	
	7,167		67,466		72,755	
6. Average travel times of sections among specific stations (hours : minutes : seconds)	Ngoc Hoi - Thu Thiem		Ngoc Hoi - Vinh		Vinh - Da Nang	
	Local	Express	Local	Express	Local	Express
	7:15:00	5:20:00	1:21:00	57:30	1:59:00	1:24:00

Indicator	Target (Five-step Case)				
5. Transportation Volume (Annual passenger × kilometer in millions)	2030	2040	2050	2060	2070
	138	2,244	7,015	14,800	82,892

Indicator	Target (Five-step Case)				
6. Average travel times of sections among specific stations (hours : minutes : seconds)	Da Nang - Nha Trang		Nha Trang - Thu Thiem*		Long Thanh - Thu Thiem
	Local	Express	Local	Express	Local
	2:11:00	1:34:00	1:38:00	1:18:30	0:11:00

(Note) *: Travel time of the express service for the section between Nha Trang - Thu Thiem is estimated with the assumption of stopping at Long Thanh Station.

Source: JICA Study Team

13. Qualitative Effects

With the implementation of this Project, the effects described below will take place. The following benefits include those that can be quantified with the above-mentioned methods and not quantified in this study. Considering these qualitative benefits as well as the result of the preliminary economic evaluation, it can be said that the Project is socially and economically viable.

13.1 Impacts on the Business Community

After commencement of operations of the HSR service, stations will be connected with 36 trains/day in 2030 and with 72 trains/day in 2040. The required time among major stations are shown in the table below and will be reduced to less than one sixth of the times required for conventional rail travel. Travel by air to or from Hanoi takes around three to four hours irrespective of distances between Hanoi and the city, and it cannot be said that all people can easily travel by air due to high prices of tickets. As with what happened in Japan after the commencement of Shinkansen operation, HSR operation will cause large impacts on the business community.

When enterprises or public offices in Japan decide to hold a meeting at a headquarters or branch office along the Shinkansen route, business persons or officials just decide on the date and time of the meeting. They are confident that they can arrive on time based on the reliability of the Shinkansen. The Shinkansen network has become basic social infrastructure for business persons or officials.

With the implementation of the Project, a backbone is formed, which connects the two largest cities of Vietnam, namely, Hanoi and Ho Chi Minh City. Implementation will bring enormous impacts to the business sector. It is expected that implementation will contribute to strengthening the international competitiveness of the Vietnamese industry by providing secured travel services for business persons.

Table S-29: Required Traveling Time among Major Stations by Conventional Rail and HSR

		Arrival Station			
Departure Station	**Type of Rail**	**Hanoi (Ngoc Hoi)**	(Unit: Hr. : Min. : Sec.)		
Vinh	Conventional	6:00:00	**Vinh**		
	HSR	0:57:30			
Da Nang	Conventional	15:56:00	9:56:00	**Da Nang**	
	HSR	2:23:00	1:24:00		
Nha Trang	Conventional	25:45:00	19:45:00	9:49:00	**Nha Trang**
	HSR	3:58:30	2:59:30	1:34:00	
Saigon (Thu Thiem)	Conventional	33:09:00	27:09:00	17:13:00	7:24:00
	HSR	5:20:00	4:21:00	2:55:30	1:20:00

(Note) The required traveling time by conventional rail is the traveling time by SE1 train (Hanoi-Ho Chi Minh City, Departure time from Hanoi; 19:30).
The required time by HSR is the traveling time for express service.
The traveling time for Nha Trang-Thu Thiem includes the stopping time (0:1:30) at Long Thanh Station
Source: JICA Study Team

13.2 Promotion of Structural Reform for Specialized/ Advanced Social Services

With the shorter traveling time required for inter-urban trips shown in Table S-29, day-trip areas will be expanded. Expansion of the day-trip areas enables structural reform of specialized/ advanced social services. With the structural reform, costs for facility construction, operation and maintenance will be reduced and better quality of the services can be provided.

For example, regarding specialized/ advanced medical facilities, conventionally each neighboring province is expected to individually expand “cancer treatment medical center,” “brain disease medical center,” “cardiovascular treatment center” etc. With the expansion of the day-trip areas, the neighboring provinces can share these facilities, and the construction, operation and maintenance costs of the provinces can be reduced. Furthermore, the quality of services of each specialized/ advanced medical center is improved, and the residents of the provinces can receive more sophisticated medical services.

The structural reform can be applied to aggregation of specialized/ advanced administrative services, financial services, etc.

13.3 Intensification/ Sophistication of Land Use in Front of the Stations and along HSR Route by Promoting Industrial Development and Attracting Industries

It can be foreseen that at HSR stations, HSR passengers and transit passengers of other transportation modes increase, and commercial activities at and around the stations will be stimulated. Also, since access from surrounding cities is improved, it is presumed that industries, especially commercial and service industries, will be promoted and developed, which in turn can promote the location of related companies. From this, the land use in front of the stations and along the HSR route will become built-up and sophisticated, leading to more effective use of national land.

13.4 Development of Regional Core Cities

Implementation of the Project will improve access among cities, especially accesses to Vinh, Da Nang, and Nha Trang where express trains stop, and commercial/ trading/ economic spheres of these cities and the catchment areas the service facilities (including private-sector facilities) located in these cities will be expanded. Based on this fact, it is expected that these cities will develop as regional core cities. The development of these cities as regional core cities will lead to an increase in users of the HSR service.

However, instead of simply waiting for the development of the regional core cities as an effect of the development of HSR, it is important to promote strategic development of these cities with well-designed urban development programs, and by attracting enterprises to these cities. It is hoped that the development of these regional core cities will lead to balanced national land development and improvement of the welfare of the whole nation.

13.5 Fostering the Unity of the Nation, Implementation of the Project as a Symbol, Raising Pride and the Patriotism of the People

This project connects the north and south of Vietnam, and the two largest cities of Hanoi and Ho Chi Minh. Together with the construction of the North-South Highway, the Project is the centerpiece of infrastructure development for people and goods going back and forth in the country. The implementation of this Project will better mobilize the people, and activate the exchange among citizens. As a result, the implementation of this project will contribute to strengthening the sense of unity of the nation.

When the first Shinkansen line was built in Japan, it was a time for Japan to join the developed countries after reconstruction from the defeat in World War II. It can be said that the Shinkansen project, together with holding of the Tokyo Olympic Games and construction of the Meishin Expressway, were symbols that Japan was meeting shoulder-to-shoulder with western countries. For Vietnam, the Project can be said to be a symbol project for becoming an upper-middle-income country like Thailand and Malaysia. Also, if the project is realized, consciousness will be shared that Vietnam has joined the ranks among countries with an advanced railway system, and that will stimulate the pride of the people.

Furthermore, it is expected that the fostered unity and increased pride of the people will lead to the rise of patriotism within the nation.

14. Conclusion and Recommendation

14.1 The Framework of this Study

The Ministry of Transport (MOT) of the Vietnamese Government and its implementing agency, the Project Management Unit (PMU) plan to submit the Pre FS of North-South HSR project to the National Assembly in 2019. For this purpose, the Vietnamese consultant, employed by MOT/PMU, prepares the Pre-FS to be submitted to the National Assembly. This survey aims to support Vietnamese consultants in the preparation of the Pre-F/S.

Since this report summarizes the information provided or explained to the Vietnamese consultants as the responsibility of the JICA Study Team, this survey report focuses on concerns from the Vietnamese consultants. They, have paid more attention to the feasibility and analysis of cargo transport on the HSR line and on building the new railway for 200 km/h speeds and improving the railway facilities in the future.

14.2 The Conclusion of this Survey

Looking at HSR systems around the world, the point at which they become feasible to launch is correlation between GDP and population. Applying this to Vietnam's economic and social development, their high-speed railway should be launched around 2030. In this study, the demand forecast was conducted by keeping the existing railway, highway network, and improvement plan of aviation infrastructure in mind. The following points were recognized.

- Capacity shortage on the north-south corridor will occur after 2030 even if existing rail infrastructure is upgraded to a double-track. This shortage will increase year by year.
- HSR is a better solution than double-tracking the existing north-south rail corridor to meet the expected growth in demand.
- However, even if HSR is developed, a small lack of transportation capacity with the projected rail infrastructure will still exist. To cope with this issue, it is necessary to double-track the bottleneck sections.

This recommends the HSR as a newly constructed line to operate at 320 km/h operation and to open in 2030. It should be dedicated to passenger services, and developed from the sections at North and South with higher traffic demands, then extended to the whole line. Conventional lines on the other hand, are suggested to be improved single-lines to maximize transportation capacity and meet the passenger and cargo demand during the construction of the HSR. However, in sections with higher transport demands, double-tracked conventional railway lines could be constructed.

The economic benefits of the Project was estimated through comparison between conditions “with the Project” and those “without the Project.”

The estimated economic viability is given in Table S-30, showing its feasibility.

Table S-30: EIRR, B/C and NPV of the Project

Indicators	Economic Internal Rate of Return (EIRR)	Benefit-Cost Ratio (B/C)	Net Present Value (NPV, USD million)
	Removed		

Source: JICA Study Team

In order to examine the financial viability of the project, the JICA Study Team adopts the Financial Internal Rate of Return (FIRR). Several cases are examined to assess the financial viability of the project from several perspectives; in particular, the ratio of Capital Expenditure (CAPEX) to be borne by public and private sectors respectively. The financial burden on the Government in each case is also estimated. The conditions for the financial analysis are summarized below:

- Section: Hanoi-HCMC
- Type: High Speed Rail (Maximum Speed 320 km/hour)
- Project Period: Construction Period: 2020-2039 (Partial COD: 2030)
- Operation Period: Partial Operation: 2030-2039, Full Operation: 2040-2069
- Operating Entity: Special Purpose Company or SPC (Private Entity)

The results of the preliminary financial analysis are shown in the following table.

Table S-31: Preliminary Financial Analysis Results

	Removed
FIRR	

Source: JICA Study Team

In terms of PPP feasibility, there is another critical point to be considered. According to the FIRR calculation assumption and results, construction periods are 10 years for partial opening and another 10 years for full opening (in total: 20 years). During that period, the cash flow on SPC will be negative, and accordingly SPC will not be able to generate profit which is not acceptable. Therefore, the Government should provide subsidies to the SPC during the said period.

14.3 Consideration for Commercialization

The history of the railway industry has demonstrated that improvements of transportation convenience form new industries along the line routes that ultimately progress economic integration. This also spreads to the society along the railway, affecting the language of people and the content of education for the next generation. The Russian Siberian Railway and the Japanese railway network have both experienced this. In recent years, the Chinese Qinghai–Tibet railway and Spanish HSR seem to aim for the expansion of the unified cultural identity, and do not focus much on profitability.

As mentioned above, railways serve the essential function to integrate regions, but on the other hand, their construction requires enormous amounts of investments, so consideration must be given to the following matters regarding commercialization.

14.3.1 Clarification of National Goals

In the commercialization of the North-South HSR, it is necessary to identify the goals as a nation, while forecasting future events as much as possible.

- Development plans along the wayside
  National plan: Vietnam's 100-Year Vision
  Regional planning: Planning for new industrial cities and areas

- The international division of labor
  Identification of Vietnamese specialty areas and fields to be trained on the premise of competition and cooperation with other countries

- Grasping the strengths and weaknesses of Vietnam

From the following points of view, grasp the strengths and weaknesses of Vietnam and take appropriate countermeasures:
Society: human resources, education, common interests, religion, ideology
Economy: market, internal investment, foreign capital
Nature: geography, natural resources

14.3.2 Enlightenment for Local Companies and People

The HSR will play an essential role in setting the foundation for the continued development of the country. When considering PPP, it is necessary to consider project schemes by hearing opinions from both the Government of Vietnam and foreign private enterprises which will be involved in the project. Also, the construction of HSR requires cooperation from citizens. Therefore, it is necessary to conduct outreach activities from the following viewpoints:

- Promotion of railway understanding
  The utility railway: Useful both for passenger and cargo, a symbol of national integration
  Conventional line: To improve regional traffic and cargo transportation
  High-speed rail: To maximize the functions as a dedicated passenger service

- Common Dreams
  HSR can contribute to achieving the following shared dreams of the Vietnamese people:
  Prosperous society: Society is enriched by new industries introducing domestic and foreign capital.
  Peaceful nation: Peace is maintained in cooperation with foreign countries.
  Diverse culture: Diversity is born by protecting tradition and adopting innovation.