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

Final Report

Disclosure Document

October 2019

JAPAN INTERNATIONAL COOPERATION AGENCY

PADECO Co., Ltd.
Yachiyo Engineering Co., Ltd.
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Table of Contents

1. Major Topics 1-1
1.1 HSR in the World (Policy and Construction Period) 1-1
1.1.1 Introduction of HSR 1-1
1.1.2 Construction of HSR and Socio-Economic Situation 1-3
1.1.3 The Motivation for the Construction of HSR 1-4
1.1.4 High Speed Railway in Vietnam 1-10
1.2 Comparison of High Speed Railway Standards and Construction Cost 1-10
1.2.1 Features of the Railway System 1-10
1.2.2 Performance of High Speed Trains 1-12
1.2.3 Standards of High Speed Railways 1-15
1.2.4 Standards of High Speed Railways in Vietnam 1-19
1.2.5 Construction Cost of High Speed Railway 1-19
1.3 Role Sharing Between HSR and Conventional Lines 1-22
1.3.1 Summary of the Previous Survey 1-22
1.3.2 This Survey 1-23
1.3.3 Induction to High Speed Railway 1-25
1.3.4 Priority in Level B1 1-26
1.4 Consideration of Mixed Cargo Train Operation on the High Speed Railway Line 1-26
1.4.1 Overview 1-26
1.4.2 Technical Issues 1-27
1.4.3 Application to High Speed Railway in Vietnam 1-29
1.4.4 Summary 1-35
1.5 Scenario for HSR Development 1-36
1.5.1 Improvement of Existing Railway 1-36
1.5.2 Phased Development of High Speed Railway 1-36
1.5.3 Speed Improvement 1-37
1.5.4 Summary 1-37
1.6 Influence on the Investment and Operation Cost caused by Train Speed 1-37
1.6.1 Investment Cost 1-37
1.6.2 Operation Cost 1-42
1.7 Night Train Operation 1-46
1.7.1 Overview 1-46
1.7.2 Japanese Experience on Conventional Lines 1-46
1.7.3 Sanyo Shinkansen Technology Investigation Committee 1-46
1.7.4 Night Train Operation 1-47
1.7.5 Study on Night Train in Vietnam 1-49

2. Necessity of Investment 2-1
2.1 How to Proceed 2-1
2.1.1 Construction Process 2-1
2.2 Forecast of Transportation Demand 2-2
2.2.1 Collection and Updating of Latest Data 2-2
2.2.2 Methodology of Forecasting 2-7

2.2.3 Updated OD Matrix 2-11
2.2.4 Update on the Current Status and Planning of the Transport System in the Target Area 2-12
2.2.5 Forecasting Scenarios (Two-step Case) 2-15
2.2.6 Forecast Results (Two-step Case) 2-16
2.2.7 Analysis and Evaluation of Forecasted Results 2-21
2.2.8 Conclusions and Recommendations (Two-step Case) 2-32
2.2.9 Alternative Case Results (Five-step Case) 2-32

3. Basic Design 3-1
3.1 Design Criteria 3-1
3.1.1 Design Speed 3-1
3.1.2 Design Load 3-1
3.1.3 Distance between Track Centers 3-1
3.1.4 Maximum Cant 3-1
3.1.5 Minimum Curve Radius 3-2
3.1.6 Maximum Gradient 3-2
3.1.7 Formation Width 3-2
3.1.8 Track Structures 3-3
3.1.9 Tunnel Shape 3-3
3.2 Route 3-4
3.2.1 Route between Stations 3-4
3.2.2 Local Route Study 3-4
3.2.3 Tracks Layout 3-6
3.2.4 Station Tracks Layout 3-6
3.3 Station Site Planning 3-9
3.3.1 Current Condition of Station Site 3-9
3.3.2 Recommendation to the Station Site Planning 3-21
3.4 Regional Development Concept Plan along the HSR 3-24
3.4.1 Necessity of HSR from the Perspective of Regional Development 3-24
3.4.2 Potential for Industrial Development in Cities along HSR 3-29
3.4.3 Examples of Regional Development Effect by TOD 3-37

4. Railway Facilities 4-1
4.1 Civil Structures (Railway, Stations) 4-1
4.1.1 Railway 4-1
4.1.2 Station and Station Facilities 4-18
4.2 Power Supply System 4-35
4.2.1 Electric Power System 4-35
4.2.2 Power Supply System for HSR 4-50
4.3 Signaling and Communication 4-73
4.3.1 Purpose and Function of Railway Signal 4-73
4.3.2 Study on the Signaling System in Vietnam HSR 4-74
4.4 Rolling Stock and Depot 4-86
4.4.1 Rolling Stock 4-86
4.4.2 Depot 4-92

4.5 Estimated Construction Costs 4-97
This section has been removed because of confidential information.

5. Railway Operation 5-1
5.1 Train Operation Plan 5-1
5.1.1 Outline 5-1
5.1.2 Outline of Train Operation Plan (Two-step Case) 5-1
5.1.3 Operation Plan 5-3
5.1.4 Train Section and Number of Trains 5-6
5.1.5 Train Schedule and Required Train Sets 5-7
5.1.6 Outline of Train Operation Plan (Five-step Case) 5-10
5.1.7 Operation Plan 5-11
5.1.8 Train Section and Number of Trains 5-11
5.1.9 Required Train Sets 5-13
5.2 Maintenance (Ground Facility, Vehicle) 5-14
5.2.1 Outline of Shinkansen Maintenance 5-14
5.2.2 Shinkansen Track Maintenance 5-19
5.2.3 Rolling Stock 5-22
5.3 Operation and Management Organization 5-30
5.3.1 Preconditions 5-30
5.3.2 Calculation of the Number of Employees 5-31
5.3.3 Organizational Structure and Employees for Control Offices (Head Office, Branch Offices, Operation Control Center) 5-32
5.3.4 Organizational Structure and Employees of Field Offices 5-34
5.3.5 Operation and Management Organization for Five-step Case 5-42
5.4 Estimated Operation and Maintenance Cost 5-43
This section has been removed because of confidential information.

6. Social Infrastructure 6-1
6.1 Laws and Regulations 6-1
6.1.1 Legal Framework for Railway Construction in Vietnam 6-1
6.1.2 Legal Framework for Shinkansen Construction in Japan 6-6
6.1.3 Efforts and Procedures Required for Introduction of HSR from Legal Standpoint 6-10
6.2 Development of the Railway Industry and Supporting Sectors 6-12
6.2.1 Background 6-12
6.2.2 Advantages of the Railway Technology 6-13
6.2.3 Development and Opportunities in Southeast Asia 6-13
6.2.4 Capacity Building 6-15
6.2.5 Conclusion 6-16

7. Preliminary Economic Evaluation 7-1
This chapter has been removed because of confidential information.

8. Project Scheme and Financing Options 8-1
8.1 Project Scheme Analysis 8-1
8.1.1 Fiscal Situation of the Vietnamese Government 8-1
8.1.2 PPP in Vietnam 8-2

8.1.3 Project Modality 8-2
8.2 Project Financing Options 8-3
8.3 Experiences of Existing HSR Project 8-4
8.3.1 Taiwan HSR 8-4
8.3.2 UK HSR 8-7

9. Preliminary Financial Analysis 9-1
This chapter has been removed because of confidential information.

10. Operation and Effect Indicators 10-1
10.1 Operation Indicators 10-1
10.2 Effect Indicators 10-1

11. Qualitative Analysis of the Project Effects 11-1
11.1 Effects of the Project Implementation and Their Quantification 11-1
11.2 Expanded Cost-benefit Analysis 11-3
11.3 Qualitative Analysis 11-4

12. Conclusion and Recommendation 12-1
12.1 The Framework of this Study 12-1
12.2 The Conclusion of this Survey 12-1
12.3 Consideration for Commercialization 12-3
12.3.1 Clarification of National Goals 12-3
12.3.2 Enlightenment for Local Companies and People 12-3
12.4 Acknowledgment 12-4

Appendices

Appendix 1-1: Study on Semi-High-Speed Railway
The cost estimation and economic/financial analysis have been removed because of confidential information.

Appendix 4-1: Project Cost (Two-step Case)
This appendix has been removed because of confidential information.

Appendix 4-2: Project Cost (Five-step Case)
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Appendix 5-1: List of Maintenance Vehicle and Equipment (Two-step Case)
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Appendix 5-2: List of Maintenance Vehicle and Equipment (Five-step Case)
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Figures

Figures on cost estimation and economic/financial analysis have been removed because of confidential information.

Figure 1.1: GDP & HSR Opening 1-3
Figure 1.2: Population and GDP per capita at HSR Opening Year 1-4
Figure 1.3: Japan's HSR Network 1-5
Figure 1.4: France's HSR Network 1-6
Figure 1.5: Germany's HSR Network 1-7
Figure 1.6: Spain's HSR Network 1-8
Figure 1.7: China's HSR Network 1-9
Figure 1.8: Target Capacity 1-25
Figure 1.9: Operable Number of Trains 1-27
Figure 1.10: Train Draft 1-28
Figure 1.11: Image of Freight Train Operation 1-30
Figure 1.12: Arrangement of Freight Facilities 1-31
Figure 1.13: Freight Station Track Alignment 1-31
Figure 1.14: EH800 for Seikan Tunnel 1-33
Figure 1.15: Container Car #200 1-33
Figure 1.16: Weekly Train Diagram 1-33
Figure 1.17: Train Diagram for the Morning 1-38
Figure 1.18: Speed and Energy Consumption 1-43
Figure 1.19: Preference Curve of Night Train 1-47
Figure 1.20: Cross over Distance and Number of Trains 1-48
Figure 1.21: Conceptual Train Diagram 1-49
Figure 1.22: Train Diagram (Stop All Trains) 1-50
Figure 1.23: Train Diagram (Slowing Down) 1-50
Figure 2.1: Construction Period of Two-step Case 2-1
Figure 2.2: Construction Period of Five-step Case 2-2
Figure 2.3: Comparison between Estimate and Actual in Population and GRDP in 2016 2-4
Figure 2.4: Actual Annual Increase Rate of Passenger by Transportation Mode in Vietnam 2-6
Figure 2.5: Actual Annual Increase Rate of Freight by Transportation Mode in Vietnam 2-6
Figure 2.6: Methodology Flow of Revision for Traffic Demand Analysis in this Study 2-7
Figure 2.7: Four Step Estimation Method for Demand Forecasting 2-7
Figure 2.8: Area Type 2-9
Figure 2.9: HSR Fare Sensitivity Analysis 2-10
Figure 2.10: Modal Split by Distance Category by Transportation Modes 2-11
Figure 2.11: Total Passenger Trip Demand in every Target Years in Vietnam 2-12
Figure 2.12: Total Freight Demand in each Target Year in Vietnam 2-12
Figure 2.13: North-South Expressway in Vietnam 2-14
Figure 2.14: Number of Passenger at every HSR Section (2030 and 2035) 2-18
Figure 2.15: Number of Passenger at every HSR Section (2040, 2045, and 2050) 2-19
Figure 2.16: Number of Passenger at every Proposed HSR Station (2030 and 2035) 2-20
Figure 2.17: Number of Passenger at every Proposed HSR Station (2040, 2045 and 2050) 2-21
Figure 2.18: Modal Share and Transition of Three Sections for Scenario 1 2-22
Figure 2.19: Modal Share and Transition of Three Sections for Scenario 2 2-22
Figure 2.20: Modal Share and Transition of Three Sections for Scenario 3 2-23
Figure 2.21: Modal Share for Scenario 3 2-23
Figure 3.1: P-16 Load 3-1
Figure 3.2: Formation Width of Viaduct (Both Side Aisle) 3-2
Figure 3.3: Formation Width of Viaduct (One Side Aisle) 3-3
Figure 3.4: Tunnel Shape 3-3

Figure 3.5: Route Alternatives around Hue........3-5
Figure 3.6: Route Alternatives around Hue........3-5
Figure 3.7: Track Layout........3-7
Figure 3.8: Station Track Layout........3-8
Figure 3.9: Distribution by Distance (Weekday)........3-25
Figure 3.10: Comparison of Urban Population along High Speed Rail
(India, Japan, Vietnam) 3-26
Figure 3.11: Transport Network of HSR, Main Roads and Railways 3-27
Figure 3.12: Land Use Planning Map of Vinh City........3-38
Figure 3.13: TOD Concept Plan around Vinh Station........3-39
Figure 3.14: Land Use Planning Map 3-41
Figure 3.15: TOD Concept Plan around Hue Station........3-42
Figure 3.16: Land Use Planning Map of Da Nang City 3-43
Figure 3.17: Location of UMRT Project (Urban Mass Rapid Transit)........3-44
Figure 3.18: TOD Concept Plan around Da Nang Station 3-45
Figure 3.19: Land Use Planning Map of Qui Nhon City 3-47
Figure 3.20: Land Use Planning Map around Dieu Tri Station........3-49
Figure 3.21: Land Use Planning Map of Nha Trang City 3-50
Figure 3.22: Land Use Planning Map Around Nha Trang Station 3-52
Figure 4.1: Typical Embankments Type 1........4-4
Figure 4.2: Typical Embankments Type 2........4-4
Figure 4.3: Typical Embankments Type 3........4-5
Figure 4.4: Typical Cuts Type 1 4-5
Figure 4.5: Typical Cuts Type 2 4-5
Figure 4.6: Typical Cuts Type 3 4-5
Figure 4.7: Typical Cuts Type 4 4-6
Figure 4.8: Typical Cuts Type 5 4-6
Figure 4.9: Typical Cuts Type 6 4-6
Figure 4.10: Typical Viaducts Type 1........4-7
Figure 4.11: Typical Viaducts Type 2........4-7
Figure 4.12: Typical Viaducts Type 3........4-8
Figure 4.13: Typical Large Bridges Type 1 4-10
Figure 4.14: Typical Large Bridges Type 2 4-10
Figure 4.15: Typical Box Culverts 4-10
Figure 4.16: Typical Tunnels........4-11
Figure 4.17: Typical Stations Type 1........4-17
Figure 4.18: Typical Stations Type 2........4-17
Figure 4.19: Typical Stations Type 3........4-17
Figure 4.20: Typical Stations Type 4........4-18
Figure 4.21: Station Type 1: 2 Island Platforms with 4 Lines, Elevated........4-19
Figure 4.22: Station Type 2: 2 Side Platforms with 4 Lines, Elevated........4-19
Figure 4.23: Station Type 3: 2 Island Platforms with 4 Lines, Ground........4-19
Figure 4.24: Station Type 4: 2 Side Platforms with 4 Lines, Ground 4-19
Figure 4.25: Drawing of Station Type 1........4-21
Figure 4.26: Drawing of Station Type 2........4-22
Figure 4.27: Drawing of Station Type 3........4-23
Figure 4.28: Drawing of Station Type 4........4-24
Figure 4.29: Generator Capacity by Power Plant Type (December 2016)........4-36
Figure 4.30: Power Generation by Power Plant Type (December 2016) 4-36
Figure 4.31: Power Sales by Customer Type (2016)........4-37
Figure 4.32: Vietnam Power Systems 4-48
Figure 4.33: Results of Simulation for System Voltage Fluctuation 4-49
Figure 4.34: Connection Wiring Diagram of the Roof Bridge Connection Transformer........4-53

Figure 4.35: Configuration Diagram of a Change-over Section 4-55
Figure 4.36: Configuration of an AC Feeding Circuit........ 4-56
Figure 4.37: Configuration of the Ground System of Analog ATC........ 4-77
Figure 4.38: Configuration of the Onboard System of Analog ATC........ 4-77
Figure 4.39: Configuration of the Ground System of Digital ATC........ 4-77
Figure 4.40: Configuration of the Onboard System of Digital ATC 4-78
Figure 4.41: Comparison of Analog ATC and Digital ATC 4-78
Figure 4.42: Configuration of the Ground System of VHSR-ATC........ 4-81
Figure 4.43: Configuration of the Onboard System of VHSR-ATC 4-81
Figure 4.44: An Example of VHSR-ATC Time Division Slot Allocation........ 4-84
Figure 4.45: Main Specification of VHSR-ATC........ 4-84
Figure 4.46: Series E5 of Tohoku Shinkansen 4-87
Figure 4.47: Economy Class of E5........ 4-89
Figure 4.48: Executive Class of E5........ 4-89
Figure 4.49: Aluminum Double Skin Extruded Structure........ 4-89
Figure 4.50: Pantograph and Deflector of Series E5........ 4-90
Figure 4.51: Compartment of CRH2E 4-92
Figure 4.52: Aisle of CRH2E........ 4-92
Figure 4.53: Ngoc Hoi Depot Track Layout 4-93
Figure 4.54: Vinh Depot Track Layout 4-93
Figure 4.55: Da Nang Depot Track Layout........ 4-93
Figure 4.56: Nha Trang Depot Track Layout........ 4-93
Figure 4.57: Thu Thiem Depot Track Layout 4-94
Figure 4.58: Ngoc Hoi Depot Location........ 4-94
Figure 4.59: Vinh Depot Location........ 4-95
Figure 4.60: Da Nang Depot Location........ 4-95
Figure 4.61: Nha Trang Depot Location 4-96
Figure 4.62: Thu Thiem Depot Location........ 4-96
Figure 4.63: Maintenance Base Track Layout........ 4-97
Figure 5.1: An Example of a Run Curve (Ngoc Hoi – Vinh)........ 5-2
Figure 5.2: Train Schedule in 2030........ 5-8
Figure 5.3: Train Schedule in 2040........ 5-8
Figure 5.4: Train Schedule in 2050........ 5-9
Figure 5.5: Inspection Trains........ 5-15
Figure 5.6: Confirmation Car........ 5-16
Figure 5.7: Work Machines........ 5-17
Figure 5.8: Maintenance System for Rolling Stock of High-Speed Railway........ 5-23
Figure 5.9: Standard Workflow of Daily Inspection 5-24
Figure 5.10: Standard Workflow of Regular Inspections........ 5-25
Figure 5.11: Standard Workflow of Bogie Inspection........ 5-26
Figure 5.12: Standard Workflow of the General Inspection........ 5-26
Figure 5.13: Workshop Organization 5-27
Figure 5.14: Location of Workshops and Depots........ 5-28
Figure 5.15: Schematic Layout of Workshop (1 of 2)........ 5-29
Figure 6.1: Overview of the Legal System in Vietnam........ 6-1
Figure 6.2: Procedure for Railway Construction in Vietnam........ 6-4
Figure 6.3: Land Utilization Planning and Land Acquisition 6-5
Figure 6.4: Procedure for Shinkansen Construction 6-8
Figure 6.5: Example of Railway Land Readjustment 6-9
Figure 6.6: Structure of Legal System and Technical Standards of HSR........ 6-11
Figure 8.1: Trend of Sales, Net Income (loss) and the Number of Annual Passengers of THSRC (2007-2015)........ 8-5
Figure 8.2: Business Scheme of HS1 8-8

Tables

Tables on cost estimation and economic/financial analysis have been removed because of confidential information.

Table 1.1: HSR in the World (Countries that have are Operating) 1-2
Table 1.2: Countries Preparing for HSR 1-2
Table 1.3: Performance of Japanese Shinkansen 1-12
Table 1.4: Performance of French TGV 1-13
Table 1.5: Performance of German ICE 1-14
Table 1.6: Standards of Shinkansen 1-15
Table 1.7: Standards of TGV 1-16
Table 1.8: Standards of ICE 1-17
Table 1.9: Standards of HSR in Asia 1-18
Table 1.10: Recommended Standards for HSR in Vietnam 1-19
Table 1.11: Factors Affecting Construction Cost of a High Speed Railway 1-20
Table 1.12: Comparison of Cross Sections 1-21
Table 1.13: Improvement Levels of Existing Lines 1-22
Table 1.14: Demand Forecast in 2030 (Number of Trains/Day) 1-22
Table 1.15: Overview of Improvement Levels for Conventional Lines 1-23
Table 1.16: Demand Forecast and Track Capacity 1-24
Table 1.17: High Speed Railway Usage Promotion Measures 1-25
Table 1.18: Curve in Conventional Lines 1-26
Table 1.19: Concept of Freight Transportation on High Speed Railways 1-29
Table 1.20: Rolling Stock for Freight Transportation 1-32
Table 1.21: Required Investment for Freight Transportation 1-34
Table 1.22: Transportation Volume of VNR 1-34
Table 1.23: O&M Cost for Freight Operation 1-35
Table 1.24: Cycle Time and Number of Roundtrips per Day 1-37
Table 1.25: Required Train Sets 1-38
Table 1.26: The Price of Rolling Stock 1-39
Table 1.27: Truck Structure and Curve Lengths (meter) 1-39
Table 1.28: Comparison of Cant 1-39
Table 1.29: Cost Estimation of Cant Correction from 200 km/h to 320 km/h 1-40
Table 1.30: Cost for Cant Correction 1-42
Table 1.31: Speed and Running resistance of Shinkansen 1-42
Table 1.32: Comparison of Power Consumption Cost (2030) 1-43
Table 1.33: Comparison of O&M Cost 1-44
Table 2.1: Outline of Two-step Case 2-1
Table 2.2: Outline of Five-step Case 2-2
Table 2.3: Population and GDP by Province in 2010 and 2016 2-3
Table 2.4: Growing Rate of Population and GDP by Province in the Future 2-5
Table 2.5: Trip Generating/Attraction Model 2-8
Table 2.6: Distribution Model 2-8
Table 2.7: Trip Generating/Attraction Model 2-10
Table 2.8: Expected Airport User Demand in HCMC Area 2-13
Table 2.9: Development Phase and Capacity of New Airport 2-13
Table 2.10: Development Phase and Capacity of New Airport 2-13
Table 2.11: Outline of Main Access Corridor between Hanoi and Ho Chi Minh 2-14
Table 2.12: Development Levels for Existing Railway and HSR 2-15
Table 2.13: Development Scenario on Existing Railway and HSR 2-15
Table 2.14: Passenger Demand Results by Transportation Modes for each Scenario 2-16
Table 2.15: Road Capacity by Target Year 2-17

Table 2.16: Other Transportation Capacity 2-17
Table 2.17: Sectional Demand – Supply Assessment for Scenario 1 2-24
Table 2.18: Sectional Demand – Supply Assessment for Scenario 2 2-27
Table 2.19: Sectional Demand – Supply Assessment for Scenario 3 2-30
Table 2.20: Passenger Volume of HSR for Five-step Case 2-32
Table 3.1: Design Maximum Speed 3-1
Table 3.2: Cant 3-1
Table 3.3: Curve Setting 3-2
Table 3.4: Maximum Gradient 3-2
Table 3.5: Track Structures 3-3
Table 3.6: Matters for Confirmation Plane Routes between Stations 3-4
Table 3.7: Matters for Confirmation Longitudinal Routes between Stations 3-4
Table 3.8: Comparison of Length around Hai Van Pass 3-5
Table 3.9: Current Activities around the Station Sites 3-21
Table 3.10: Total Area (km^2) of Districts which have a Main Road or Railway Connecting to the HSR in each Province and its Coverage Rate 3-28
Table 4.1: Types and Performances of Slope-Protection Works for Embankments 4-2
Table 4.2: Types and Performances of Slope-Protection Works for Cuts 4-2
Table 4.3: Design Limit Values for Girder Deflection Based on Running Safety under Normal Conditions 4-8
Table 4.4: Design Limit Values of Vertical Unevenness of Track Surface Based on Running Safety under Normal Conditions 4-8
Table 4.5: Design Limit Values for Angular Rotation of Track Surface Based on Running Safety under Normal Conditions 4-9
Table 4.6: Limit Values for Differential Displacement of Track Surface during Earthquakes ... 4-9
Table 4.7: Tunnel Excavating Method 4-11
Table 4.8: Division of Tunnel Heading Section 4-12
Table 4.9: Division of Tunnel Heading Section 4-15
Table 4.10: Tunnel Auxiliary Method 4-15
Table 4.11: Outline of Station Elements 4-20
Table 4.12: Examples of Universal Design (Space for Moving) 4-26
Table 4.13: Examples of Universal Design (Space for Acting) 4-28
Table 4.14: Examples of Universal Design (Information) 4-28
Table 4.15: Examples of Universal Design (Environment) 4-31
Table 4.16: Examples of Universal Design (Safety and Security) 4-32
Table 4.17: Examples of Universal Design (Rolling Stock) 4-34
Table 4.18: Generator Capacity by Power Plant Type (December 2016) 4-35
Table 4.19: The National Power Transmission System Controlled by the National Power Transmission Corporation (NPT) (December 2016) 4-37
Table 4.20: The Power Distribution Networks (December 2016) 4-37
Table 4.21: Power Sales Growth 4-38
Table 4.22: Generator Capacity by Power Plant Type within the 7th National Power Development Plan 4-38
Table 4.23: Power Generation by Power Plant Type within the 7th National Power Development Plan 4-38
Table 4.24: Forecast of Extensions in Transformer Capacities and Transmission Lines by 2030 4-39
Table 4.25: Lists of 220 kV New Transformer Lines in the Northern Area 4-40
Table 4.26: Lists of 220 kV New Transformer Lines in the Central Area 4-41
Table 4.27: Lists of 220 kV New Transformer Lines in the Southern Area 4-42
Table 4.28: Lists of 220 kV New Transmission Lines in the Northern Area 4-43
Table 4.29: Lists of 220 kV New Transmission Lines in the Central Area 4-45
Table 4.30: Lists of 220 kV New Transmission Lines in the Southern Area 4-46

Table 4.31: Voltage of Overhead Contact Line 4-51
Table 4.32: Characteristics of Various Feeding Systems........ 4-51
Table 4.33: Standard Transformer........ 4-59
Table 4.34: Estimated and Rated Capacity........ 4-60
Table 4.35: Standard Capacity and Short Circuit Strength of Automatic Transformer........ 4-62
Table 4.36: Types of Overhead Contact Line and Standard Tension........ 4-63
Table 4.37: Standard Height of Overhead Contact Lines........ 4-63
Table 4.38: Installation Range of Steady Arm 4-63
Table 4.39: Range of Pull-off Arm........ 4-64
Table 4.40: Kind and Standard Tension of Feeder 4-64
Table 4.41: Application Sections of Various Protection Systems........ 4-64
Table 4.42: Types of Protective Wires........ 4-65
Table 4.43: Standard Spans 4-65
Table 4.44: Electrical Equipment Technical Standard (Article 2)........ 4-70
Table 4.45: Equipment that Receives Electricity 4-70
Table 4.46: Equipment that Receives Electricity 4-71
Table 4.47: General Comparison between 6.6 kV and 20 kV 4-71
Table 4.48: Necessary Information on Safe Driving........ 4-74
Table 4.49: Modernization of Transport Policies on the Tokaido Shinkansen........ 4-75
Table 4.50: Advancement of Transport Capacity on the Tokaido Shinkansen........ 4-76
Table 4.51: Main Differences among DS-ATC, RS-ATC, and VHSR-ATC 4-82
Table 4.52: Basic Specifications of Rolling Stock for VHSR........ 4-88
Table 4.53: Maintenance Intervals of Rolling Stock........ 4-90
Table 4.54: Overview of each Depot........ 4-92
Table 5.1: Operating Time (Ngoc Hoi → Thu Thiem)........ 5-4
Table 5.2: Operating Time (Thu Thiem → Ngoc Hoi)........ 5-5
Table 5.3: Passenger Volume between Stations (Two-step Case) 5-6
Table 5.4: Number of Trains by Section (Two-step Case) 5-7
Table 5.5: Number of Train Sets per Depot (Two-step Case) 5-10
Table 5.6: Passenger Volume between Stations (Five-step Case) 5-12
Table 5.7: Number of Trains by Section (Five-step Case) 5-13
Table 5.8: Number of Train Sets per Section (Five-step Case)........ 5-13
Table 5.9: Number of Train Sets per Depot (Five-step Case) 5-14
Table 5.10: Improvement of Component and Material 5-18
Table 5.11: Comparison of Ballast Track........ 5-20
Table 5.12: Track Structure of Shinkansen 5-20
Table 5.13: Track Structure and Applied Line of the Tohoku Shinkansen (Tokyo - Morioka)........ 5-21
Table 5.14: Economic Calculation of Slab Track........ 5-21
Table 5.15: The Proportion of Slab and Ballast Track of Tohoku Shinkansen (Tokyo – Morioka) 5-22
Table 5.16: Type of Rolling Stock........ 5-23
Table 5.17: Work Area of Workshop 5-27
Table 5.18: Number of Train Sets for 2030, 2040 and 2050........ 5-31
Table 5.19: Railway Structure of Vietnam HSR 5-31
Table 5.20: Track Structure of HSR........ 5-31
Table 5.21: Number of Employees for HSR for 2030, 2040 and 2050........ 5-32
Table 5.22: Organization and the Number of Employees for the Head Office, Vietnamese HSR Managing Company 5-32
Table 5.23: Organization and the Number of Employees for Branch Offices, Vietnamese HSR Managing Company (Hanoi Branch Office and HCMC Branch Office) 5-33

Table 5.24: Number of Employees at the Operation Control Center (OCC) (Same for Hanoi Branch and HCMC Branch) 5-34
Table 5.25: Number of Employees at Field Offices 5-34
Table 5.26: Number of Passengers and Station Size 5-36
Table 5.27: Number of Employees at each Station 5-37
Table 5.28: Number of Employees at the Train Driver/Conductor Depot 5-38
Table 5.29: Number of Employees at the Inspection Base 5-38
Table 5.30: Number of Employees at the Rolling Stock Workshop 5-39
Table 5.31: Number of Employees at the Equipment/Facilities Depot 5-40
Table 5.32: Number of Employees at the Power Supply Depot 5-41
Table 5.33: Number of Employees at the Signaling/Telecommunications Depot 5-41
Table 5.34: Number of Employees at the Material Center 5-42
Table 5.35: Number of Train Sets for Five-step Case 5-42
Table 5.36: Number of Employees at Each Office for Five-step Case 5-43
Table 5.37: Number of Employees at Each Office for Two-step Case 5-43
Table 6.1: New Railway Law (Law 03/2017/L-CTN) 6-2
Table 6.2: Chapter 8 - High-Speed Railways 6-2
Table 6.3: Decree on Specifically Stipulating and Guiding the Implementation of Several Articles in the Railway Law (Decree 14/2015/ND-CP) 6-3
Table 6.4: Law on Construction (Law 50/2014/QH13) 6-3
Table 6.5: Nationwide Shinkansen Railway Development Act (No. 71, 1970) 6-7
Table 6.6: Regulations on Land Control 6-8
Table 6.7: The Guidance for the Management of Safety for Construction Works in Japanese ODA Project 6-10
Table 6.8: Sample Timeline for Legal System and Technical Standards 6-12
Table 8.1: Investment Budget of the Government and PCs (2018) 8-1
Table 8.2: External Borrowing Status and Borrowing Ceiling of the Government 8-2
Table 8.3: Pros and Cons of Financial Options 8-3
Table 8.4: Project Overview of Taiwan HSR 8-4
Table 8.5: Project overview of High Speed 1 8-7
Table 10.1: Proposed Operation Indicators 10-1
Table 10.2: Proposed Effect Indicators 10-2
Table 10.3: Targets of Operation Indicators 10-3
Table 10.4: Targets of Effect Indicators 10-3
Table 11.1: Effects by the Implementation of the North-South High Speed Rail Project 11-2
Table 11.2: Required Traveling Time among Major Stations by Conventional Rail and HSR 11-5
Table 12.1: EIRR, B/C and NPV of the Project 12-2
Table 12.2: Preliminary Financial Analysis Results 12-2

Abbreviations

AC	Alternating Current
ACB	Air Circuit Breaker
ADB	Asian Development Bank
AFTA	ASEAN Free Trade Area
ANFO	Ammonium Nitrate Fuel Oil
ASEAN	Association of Southeast Asian Nations
AT	Auto Transformer
ATC	Automatic Train Control
ATP	AT Post
ATS	Automatic Train Stop
AVE	Alta Velocidad Española
B/C	Benefit-Cost Ratio
BIL	Basic Impulse-Insulation Level
BLT	Build-Lease Service-Transfer
BOO	Build-Own-Operate
BOT	Build-Operate-Transfer
BRT	Bus Rapid Transit
BT	Booster Transformer
BT	Build-Transfer
BTL	Build-Transfer- Lease Service
CAPEX	Capital Expenditure
CBD	Central Business District
CIC	Centralized Information Control
COSMOS	Computerized Safety, Maintenance and Operation Systems of Shinkansen
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
CS	Copper-Clad Steel
CSC	Centralized Substation Control
CTC	Centralized Traffic Control
CTRL	Channel Tunnel Rail Link
CVM	Contingent Valuation Method
DAC	Development Assistance Committee
DC	Direct Current
DPC	District People's Committee
DS-ATC	Digital communication & control for Shinkansen-ATC
EB	Emergency Brake
EIRR	Economic Internal Rate of Return
EJ	Expansion Joint
EMU	Electric Multiple Unit
EVN	Vietnam Electricity
ENVCPC	Central Power Corporation
EVNHANOI	Hanoi Power Corporation

EVNHCMC	Ho Chi Minh City Power Corporation
EVNSPC	Southern Power Corporation
FEP	Flexible Electric Pipe
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GIS	Gas Insulated Switchgear
GNI	Gross National Income
GRDP	Gross Regional Domestic Product
GRP	Gross Regional Product
HCMC	Ho Chi Minh City
HSR	High Speed Rail
HST	High Speed Train
HS1	High Speed 1
ICE	InterCity Express
IE	Institute of Energy
IGBT	Insulated Gate Bipolar Transistor
ISO	International Organization for Standardization
IT	Information Technology
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JNR	Japanese National Railways
JPY	Japanese Yen
JR	Japan Railways
JRE	Japan Railways East
JST	JICA Study Team
LBS	Load Break Switch
LCC	Low Cost Carrier
LCR	London and Continental Railway
LCX	Leaky Coaxial Cable
LED	Light Emitting Diode
LRT	Light Rail Transit
LZB	Linienzugbeeinflussung
MAGLEV	Magnetic Levitation
MAHSR	Mumbai Ahmedabad High Speed Railway
MCCB	Molded Case Circuit Breaker
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MOC	Ministry of Construction
MOIT	Ministry of Industry and Trade
MOT	Ministry of Transport
MP	Master Plan
MTPIP	Mid-Term Public Investment Plan
NATM	New Austrian Tunneling Method
NHSRC	National High Speed Rail Corporation Limited

NPCEVN	Northern Power Corporation
NPT	National Power Transmission Corporation
NPV	Net Present Value
NTV	Nuovo Trasporto Viaggiatori
OCC	Operation Control Center
OD	Origin Destination
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating Expenditure
O&M	Operation and Maintenance
PC	Prestressed Concrete
PC	Programmable Controller
PDCA	Plan-Do-Check-Act
PETIT	Strategic Plan of Infrastructure for Transportation
PMU	Project Management Unit
PPP	Public-Private Partnership
PRC	Programmed Route Control
PWM	Pulse Width Modulation
RC	Reinforced Concrete
RCEP	Regional Comprehensive Economic Partnership
RL	Rail Level
RS-ATC	digital Radio communication and control for Shinkansen ATC
R&D	Research and Development
SCADA	Supervisory Control and Data Acquisition
SCF	Standard Conversion Factor
SMIS	Shinkansen Management Information System
SN	Signal to Noise
SNCF	Société Nationale des Chemins de fer Français
SP	Sectioning Post
SPC	Specific Purpose Company
SS	Substation
SSP	Sub-Sectioning Post
TBM	Tunnel Boring Machine
TEDI	Transport Engineering Design Inc.
TEN-T	Trans-European Transport Networks
TGV	Train à Grande Vitesse
THSRC	Taiwan High Speed Rail Co., Ltd.
TOD	Transit Oriented Development
TPP	Trans-Pacific Partnership Agreement
TVM	Transmission Voie-Machine
UIC	International Union of Railways
UK	United Kingdom of Great Britain and Northern Ireland
UMRT	Urban Mass Rapid Transit

UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United State Dollar
VGF	Viability Gap Funding
VITRANSS2	The Comprehensive Study on the Sustainable Development of Transport System in Vietnam
VND	Vietnam Dong
VNR	Vietnam Railways
VNRA	Vietnam Railway Administration
VHSR	Vietnam High Speed Rail
VOC	Vehicle Operation Cost
VVVF	Variable Voltage Variable Frequency
WB	World Bank

1. Major Topics

1.1 HSR in the World (Policy and Construction Period)

1.1.1 Introduction of HSR

(1) HSR Prehistory

The modern railway began with the Liverpool and Manchester railway in the UK, which opened in 1830. A steam locomotive traction was installed instead of the previous horse drawing, and its maximum speed was 58 km/h on a track gauge of 1,435 mm. This became the standard of subsequent railway development, spreading across the world. However, in Japan in 1872 and Vietnam in 1885, the railways opened on 1,067 mm and 1,000 mm track gauges respectively. The reason these countries did not apply the standard gauge was to save construction costs.

The beginning of electric cars replacing steam locomotives was in 1881, and the invention of the track circuit was in 1872. The accumulation of railway technology gradually advanced, and in 1955, the French National Rail set a record speed of 331 km/h. However, as a worldwide trend at the time, there was a strong belief that railway demand will decline when the age of automobiles and aircraft arrives.

(2) Concept of Shinkansen

Japanese HSR called Shinkansen began its operation in 1964, at a section of 515 km between Tokyo and Osaka. At the time of opening, the maximum speed was 210 km/h, but currently, it is up to 285 km/h. The Shinkansen has overturned the traditional railway concept in the following ways:

- Elimination of railroad crossings
  The entire railway was elevated, and level crossings were eliminated
- Weight reduction of vehicles
  The axle load was reduced by the power distribution system and method, and the burden on the structure was reduced.
- Equipment assisted train control
  By utilizing equipment for forward monitoring and train control, safe, high speed transportation was made possible[1]. With great success technically, financially and socially, the Tokaido Shinkansen has extended all over Japan.

(3) Propagation to the World

With the success of the Shinkansen, the significance of railways was re-recognized globally. The movement of increasing railway speed expanded to various countries, and the construction of new lines and improvement of conventional lines spread. The basic idea was the “elimination of level crossings,” “weight reduction of vehicles” and “equipment assisted train control” as described earlier.

In Europe, France and Germany constructed their networks and are now expanding to neighboring countries. In Asia, South Korea and Taiwan are leading, and nowadays, construction in China is progressing. The following table shows the countries where the operation of high speed railways has been started so far.

[1] Previous railways were operated by the driver paying close attention in front, and if there was any abnormality, the train was stopped by emergency brakes. The distance that is necessary to stop a train operating at a maximum speed is called the braking distance, and it was ruled for the train not to be operated at a speed which it cannot stop within the braking distance. The braking distance varies from country to country, but it is 600 m in Japan. As a result, even if the train had a high braking performance, the operating speed was limited to 130 km/h or less.

Although there is no clear definition of HSR, UIC (International Union of Railways) labels a railway which is over 250 km/h on a new line, and over 200 km/h on an improved conventional railroad as HSR.

Table 1.1: HSR in the World (Countries that Have Are Operating)

Opening Year	Country	Maximum Speed km/h 2018	Length at Opening Km	Operating Line km 2018	In Construction km	New/Improved Line
1964	Japan	320	515	3,041	402	New Line
1981	France	320	419	2,776	0	New Line
1991	Germany	300	357	1,658	185	New Line
1992	Italy	300	122	981	67	New Line
1992	Spain	300	471	2,938	904	New Line
1997	Belgium	300	72	209	-	New Line
2003	England	300	74	113	230	New Line
2004	South Korea	305	330	887	-	New Line
2007	Taiwan	300	345	354	-	New Line
2008	China	350	148	26,869	10,738	New Line
2009	Netherlands	300	120	120	-	New Line
2009	Turkey	250	232	724	1,395	New Line
2012	Australia	250	86	48	218	New Line
2000	United States	240	735	735	192	Improved Line
2004	Switzerland	250	52	144	15	Improved Line
2015	Poland	200	224	224	-	Improved Line

Note: An opening year is the commencement of service of the new line for countries with both new and improved lines.
Source: High Speed Lines in the World, 20th (UIC, April 2018), "High Speed Trains of the World" (Miura and Akiyama, 2008)

Furthermore, there are many countries that are preparing for the operation of high speed railways. The status is shown in the below Table.

Table 1.2: Countries Preparing for HSR

Region	Countries	In Construction Km	In Planning Km	In Long-Term Planning Km	Total Km
Asia	Bahrain and Qatar	-	-	180	180
	India	-	508	4,126	4,634
	Indonesia	-	712	-	712
	Iran	-	1,351	1,499	2,850
	Kazakhstan	-	-	1,011	1,011
	Malaysia / Singapore	-	350	-	350
	Saudi Arabia	453	-	-	453
	Thailand	-	615	2,262	2,877
	Vietnam	-	-	1,541	1,541
Europe	Czech Republic	-	-	810	810
	Denmark	56	-	-	56
	Estonia, Latvia, Lithuania	-	-	740	740
	Norway	-	-	333	333
	Portugal	-	-	596	596
	Russia	-	770	2,208	2,978
	Sweden	11	-	739	750

Region	Countries	In Construction Km	In Planning Km	In Long-Term Planning Km	Total Km
Others	Australia	-	-	1,749	1,749
	Brazil	-	-	511	511
	Canada	-	-	290	290
	Egypt	-	-	1,210	1,210
	Mexico	-	-	210	210
	Morocco	200	-	1,114	1,314
	South Africa	-	-	2,390	2,390

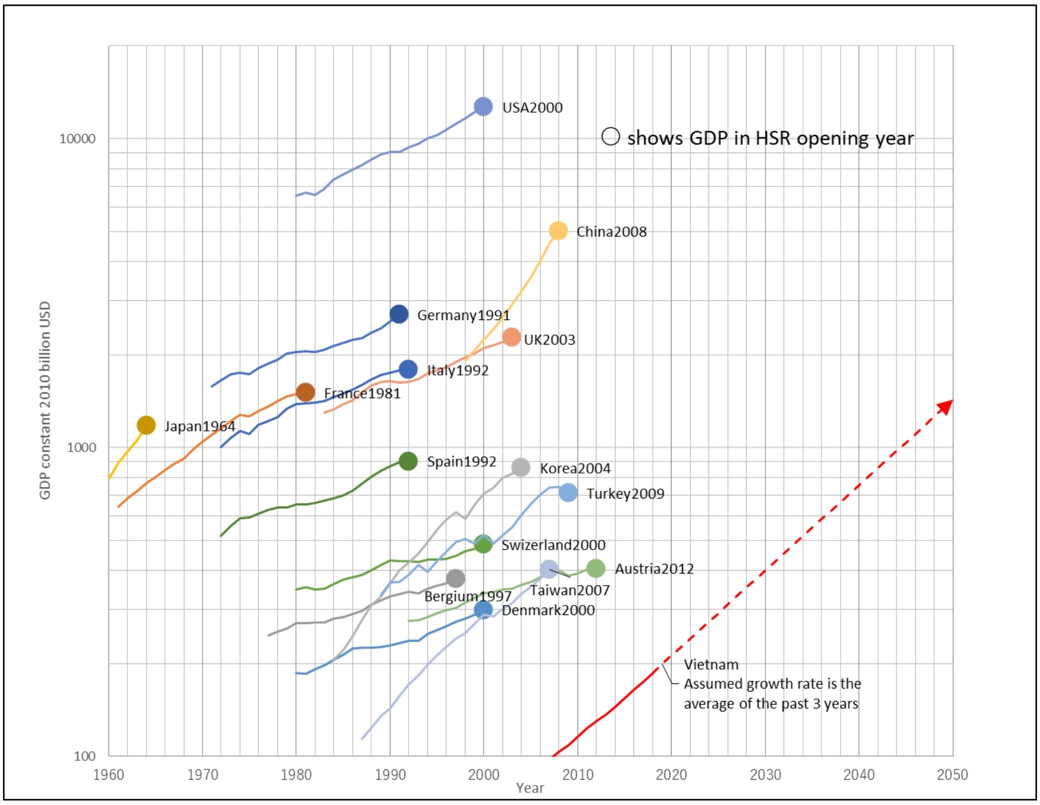
Source: High Speed Lines in the World, 20th (UIC, April 2018)

1.1.2 Construction of HSR and Socio-Economic Situation

The timing of the construction of HSR may be affected by the population and economic strength of the country concerned. This section considers the timing of construction, as seen from socio-economic situations (such as population and GDP).

(1) Relation of Real GDP and HSR Opening

The below figure shows the progress of GDP leading up to the opening of high speed railways in various countries, with the horizontal axis showing the fiscal year and the vertical axis showing the GDP. The circle in the figure (◯) shows the GDP in the opening year of HSR. By 2030, Vietnam's GDP will reach 400 billion USD, which is the GDP level of other countries when they launched HSR. Therefore, opening HSR in 2030 seems appropriate. The dotted red line shows the trend of GDP in Vietnam on the assumption that the future growth rate is the average of the past 3 years.



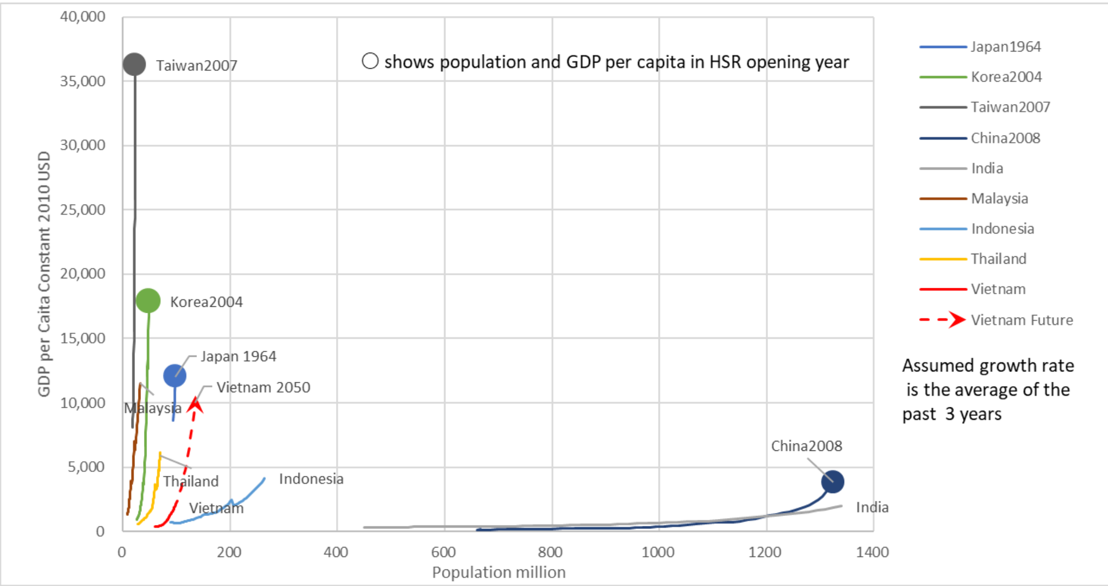
Source: World Development Indicators (World Bank, 2018), High Speed Lines in the world 20th (UIC, 2018)

Figure 1.1: GDP & HSR Opening

(2) Relation with Population and per capita GDP

The following figure shows the relationship between population and per capita GDP in Asian countries. Japan, Korea, Taiwan, and China have implemented high speed railways. The circle in the figure (◯) shows the opening year of such countries.

India, Indonesia, Vietnam, Thailand, and Malaysia are countries where the development of high speed railways is a popular topic. The red line indicates the relation between population and per capita GDP in Vietnam, and the dotted red line shows the future trend until 2050 (assuming their growth ratios to be the same as the average of the past 3 years). The construction of a high speed railway takes about 10 years from planning to opening. Therefore, it seems that Vietnam has reached the time to consider the introduction of a high speed railway.



Source: World Development Indicators (World Bank, 2018), High Speed Lines in the world 20th (UIC, 2018)

Figure 1.2: Population and GDP per capita at HSR Opening Year

1.1.3 The Motivation for the Construction of HSR

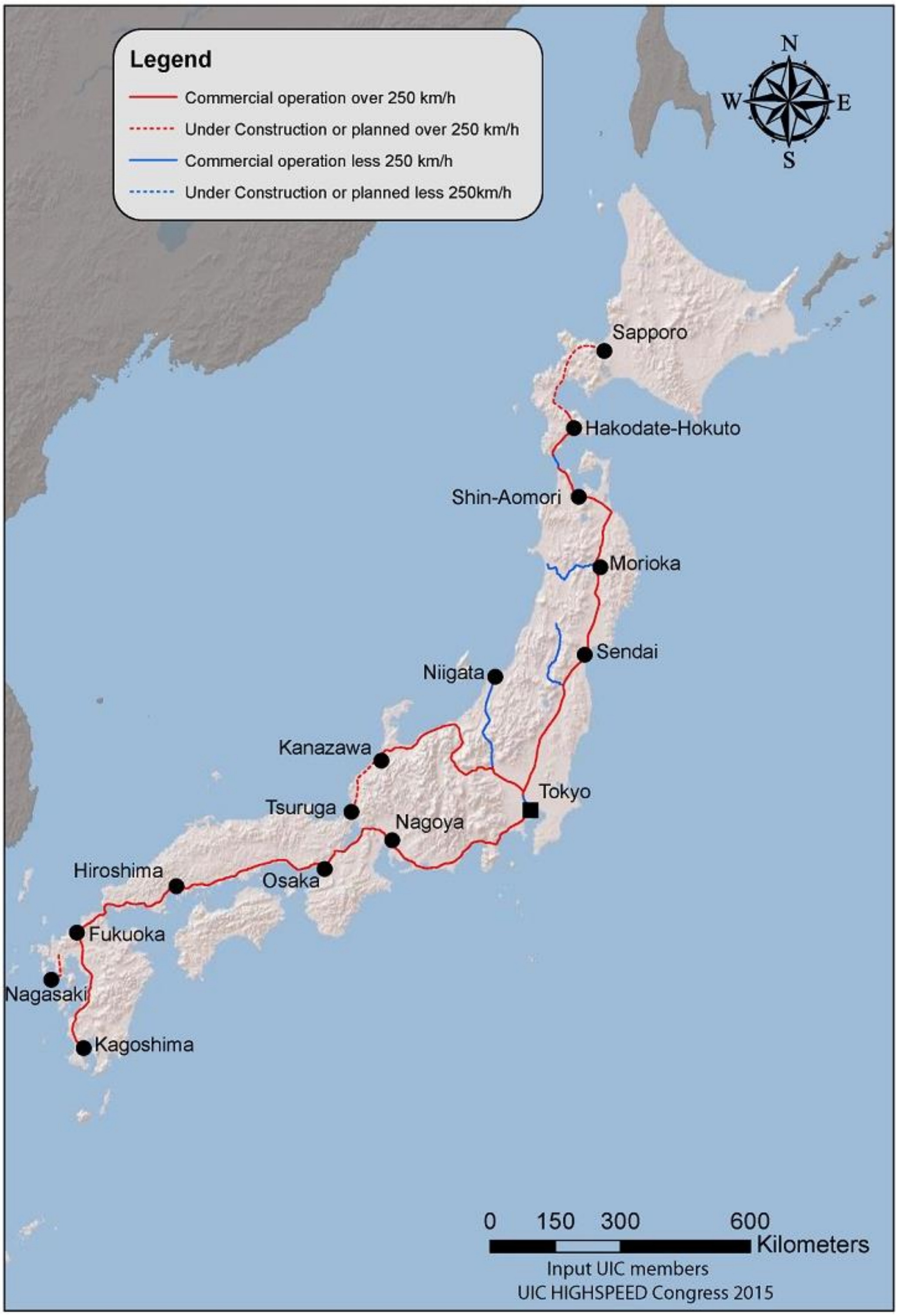
The reasons for the construction of high speed railway are as follows.

(1) Japan

The Shinkansen was inaugurated shortly before the opening of the Olympic Games in Tokyo in 1964, as the world's first high speed rail service. Today, its network expands to Kyushu Island in the south and Hokkaido Island in the north, via submarine tunnels for both islands. The total length of the network has reached 3,041 km in 2018. The objective of the Tokaido Shinkansen (the initial line) was to improve services by solving capacity restraints and reducing the travel time between Tokyo and Osaka, down to four hours with a distance of 515 km with the Shinkansen's speed of 210 km/h. Currently, the trip duration is two and a half hours. Thus, the primary motivation was in response to mobility demand due to rapid economic growth, and to offer more capacity in congested corridors with favorable characteristics for railway transportation.

Initially, the Shinkansen service was planned to serve both freight and passengers. However, the huge passenger demand and maintenance needs (carried out mainly at night) favored passenger orientation. Also, its separation from the conventional rail services allowed it to avoid problems derived from these traditional services and its aging infrastructure.

In the past, the Shinkansen was developed in a region with great demand, but nowadays is expanding throughout the whole country aiming for contribution to regional development.



Source: High Speed Database & Maps (UIC, High Speed Congress 2015)

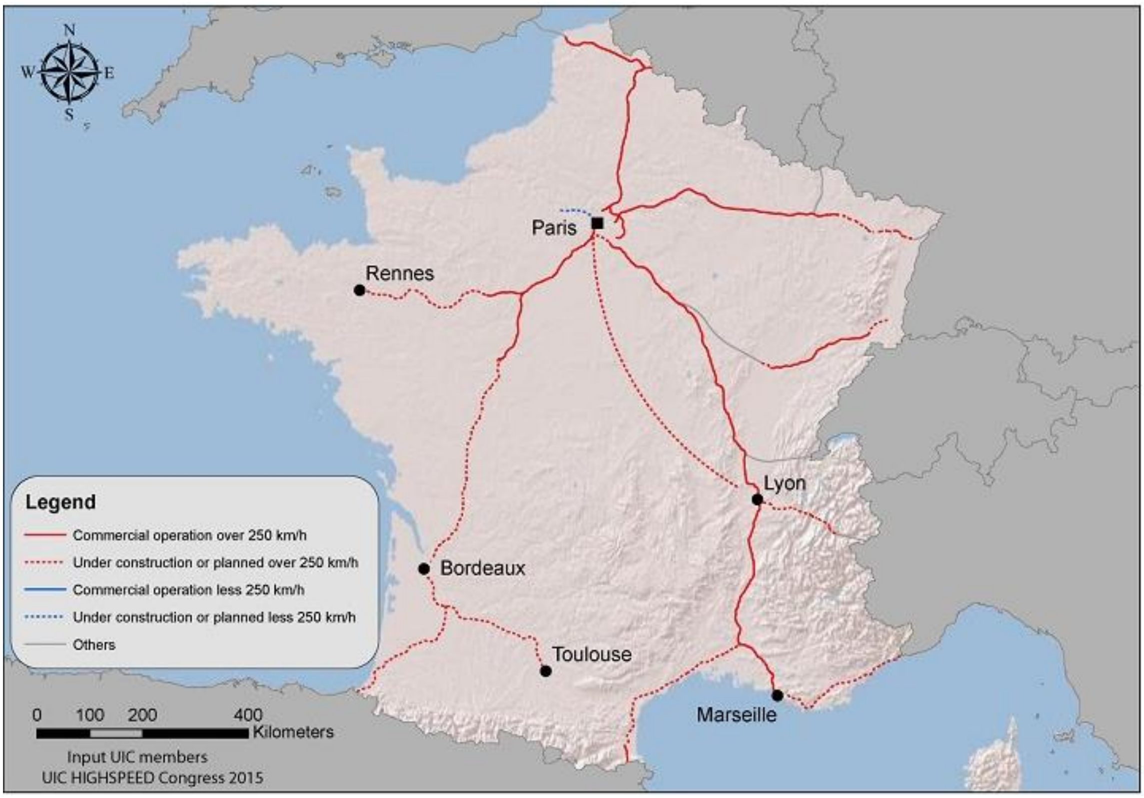
Figure 1.3: Japan's HSR Network

(2) France

After recovering from the effects of World War II, the railway competitiveness with respect to road and air transport continuously deteriorated. As a first step to improve the competitiveness of railways, SNCF[2] introduced a HSR line (Train à Grande Vitesse - TGV) between congested Paris - Lyon.

France decided to create separate new lines along congested links, and shared the conventional routes and stations where new construction was expensive. As a result, and in contrast to Japan, France has a mixed HSR infrastructure system with the conventional rail. With this system, the train speed is around 240 - 320 km/h on the high speed line; however, it is less than 200 km/h on the conventional line. Also, when the TGV train enters the existing line, it must follow the signals of the conventional line.

The TGV put an emphasis on passenger transport that is easy to demonstrate the characteristics of high speed railway and excluded cargo transport. The introduction of TGV began with crowded sections. The development of the TGV began on the corridor with the most serious congestion problems.



Source: High Speed Database & Maps (UIC, High Speed Congress 2015)

Figure 1.4: France's HSR Network

2 SNCF: Société Nationale des Chemins de fer Français, National railway of France

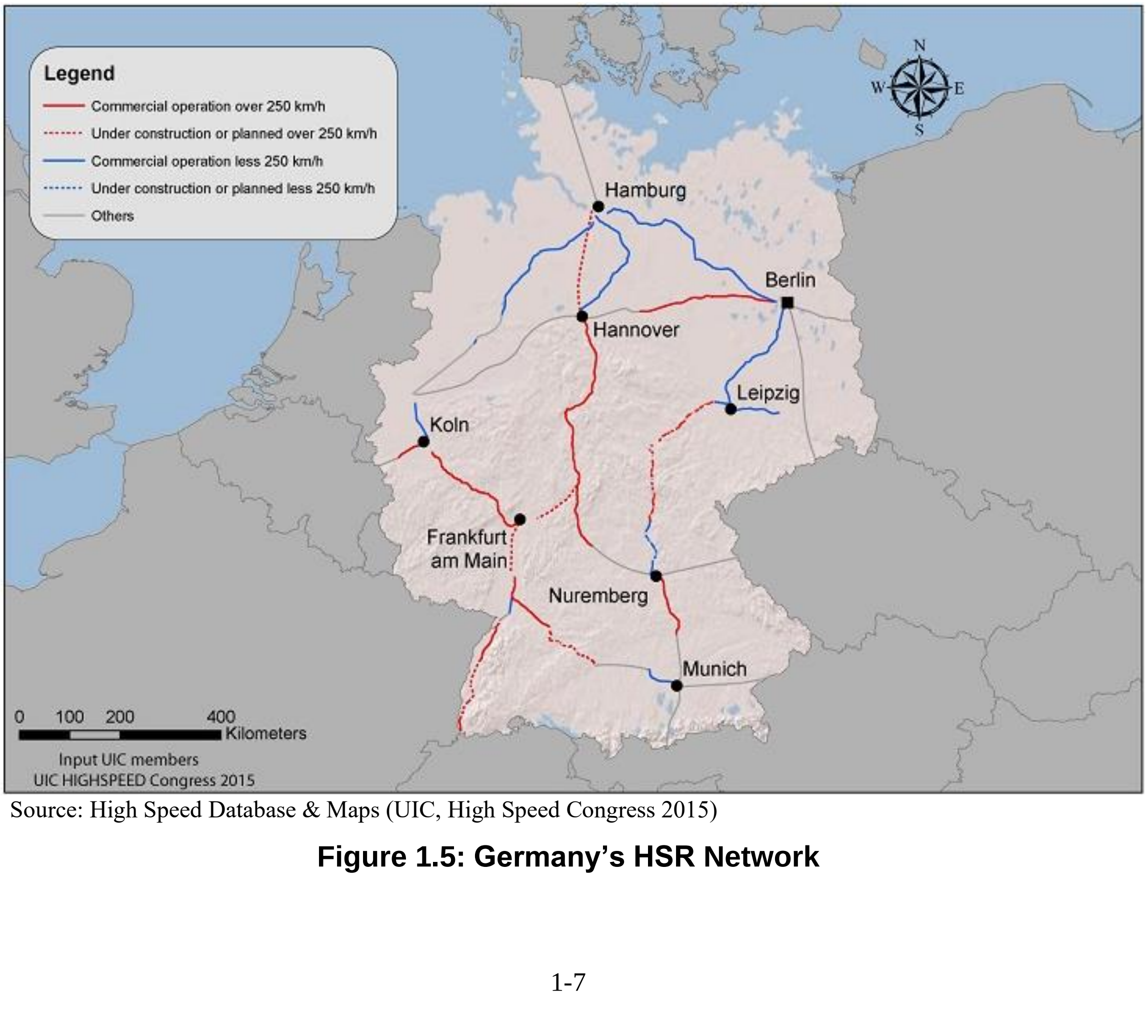
(3) Germany

In Germany, since the railway network was divided in the east and west with the Cold War, the reconstruction of the freight transport corridor connecting the industrial areas in the south from the northern seaport was the main goal. After the country's political reunification, the need to connect east and west became an additional priority.

The Inter City Express (German HSR) began operation in June of 1991, a decade after France. The reasons for the delay were the country's mountainous terrain and the complicated procedures to obtain the necessary legal and political approval to begin construction. The first routes chosen in Germany were the line Hanover - Wurzburg, and Mannheim - Stuttgart. Both were mixed lines combining passenger and freight traffic, which is different from the Japanese and French HSR that focus on passenger dedicated service.

The network quickly grew with the addition of a route Wolfsburg - Berlin in 1998 - known as the east-west route - which is different from the traditional north-south direction. This route was a symbol of the political unification between the West and East Germany. The need to connect the new political capital, Berlin, with the cities in the country's west was the reason behind this decision.

Later, the line between Cologne and Frankfurt entered into service in 2002, and the line between Nuremberg and Munich in 2006. Both newly constructed lines were exclusively for passenger traffic, which is why their cruising speeds can reach 300 km/h, in contrast to the rest of the routes that opted for mixed passenger and freight traffic in exchange for slower speeds. In fact, on the same Nuremberg - Munich line, there are upgraded sections in which the train's speed does not surpass 200 km/h.



Source: High Speed Database & Maps (UIC, High Speed Congress 2015)

Figure 1.5: Germany's HSR Network

(4) Spain

In Spain, high speed rail is called AVE (Alta Velocidad Española) which means Spanish High Speed. It began operations in 1992 between Madrid–Seville, just in time for the Barcelona Olympic Games and Seville Expo '92. The line applied the international track gauge standard of 1,435 mm enabling the direct operation with the French system, even though most of the railway network uses the gauge of 1,668 mm in Spain. As of 2018, the Spanish AVE system is the longest HSR network in Europe with 2,852 km and the third longest in the world, following Japan and China. According to the PETIT (Strategic Plan of Infrastructure for Transportation) formulated by the government in 2005, a total of EUR 240 billion will be invested, of which 48% will be assigned to railway. It plans to construct 10,000 km of high speed railway network by 2020 so that 90 percent of the population would live within 50 km of a station served by AVE. Most of the Spanish high speed railway plans are prescribed in TEN-T (Trans-European Transport Networks) approved by the EU in 1990, which aims to encourage the revitalization of the internal market of EU. Much of the construction cost depends on not only the national budget and private funds by PPP, but also assistance from the EU such as the European regional development fund, cohesion fund, and TENT-T plan support money.

The main objective of AVE is to connect the country's political and economic capital, Madrid with all the provincial capitals by high speed rail without emphasis on demand. The demand for AVE has not reached the minimum threshold for the European Commission to favor construction.

Source: High Speed Database & Maps (UIC, High Speed Congress 2015)

Figure 1.6: Spain's HSR Network

(5) China

The rapid development of China occurred after political reforms in 1978. The GDP growth rate has been around 10% per year over the past 30 years, due to the shift to a market economy. China intends to modernize land transportation to improve the economic productivity of the country. To increase freight transportation capacity, road and railway network was improved. The main issue of the Chinese transport policy from the end of the 20th century to the beginning of the 21st century was the improvement of productivity and of logistics in freight transportation.

In 2003's medium and long-term investment plan, the target of the HSR network until 2020 was the separation of passenger and freight trains by construction of dedicated passenger lines. It has solved the bottleneck, alleviated the congestion of roads, and improved productivity and regional development.

In addition, to increase transport capacity, China also improved the speed of the existing network for the improvement of productivity and logistics. For this reason, the Ministry of Railways designed six rounds of acceleration of services between 1997 and 2007 to increase the average service speed on existing tracks, just before the incorporation of high speed rail. Above and beyond these objectives, the Chinese government has formulated a concept of the network, rather than of individualized corridors. In this respect, the goal set by the Chinese government has been to connect all populations of provincial capitals with a minimum of 500,000 inhabitants and to connect 90 percent of the population by high speed rail by the year 2020.

Source: High Speed Database & Maps (UIC, High Speed Congress 2015)

Figure 1.7: China's HSR Network

1.1.4 High Speed Railway in Vietnam

The following items are considered during the development of high speed railways:

1) Economic ability to develop and operate high speed railway
2) Transport capacity that existing railways can offer
3) Social requirements for safety, high speed, and comfort provided by the high speed railway
4) Unification of national consciousness through improvement of high speed railway lines
5) International competition in attracting industries from foreign countries.

While the development of a high speed railway has a great social effect, it takes a huge amount of financial resources. Therefore, it is necessary to choose the course of direction under national consensus.

1.2 Comparison of High Speed Railway Standards and Construction Cost

1.2.1 Features of the Railway System

In this section, high speed railway is defined as a railway that operates in the main sections at 200 km/h or more based on the Vietnamese Railway Law. Regarding high speed railway in the world, comparisons of their characteristics are as follows.

(1) Presence or Absence of Direct Operation with Conventional Lines

To secure the operating stability of the train, it is not possible to realize a high speed railway with a meter gauge track; it is necessary to set it to 1,435 mm or more. For this reason, when the conventional railway is a meter gauge, through operation between high speed rail and conventional line is impossible. This case is consistent with the Japanese Shinkansen. Spain's existing railway is a broad gauge of 1,668 mm and cannot be operated directly with the 1,435 mm high speed railway to France as well. If there is no direct operation with the conventional line, high speed operation on the whole line becomes possible without any restrictions caused by conventional lines.

If the track of the conventional railway is a standard gauge, the through operation is possible by devising the power and signaling system. While there are advantages such as through operation into conventional railway stations, it is difficult to change the facilities of conventional lines for high speed railway. Many accidents of HSR trains occurred while being operated on a conventional line.

(2) Concentrated Traction System and Distributed Traction System

Japan applies the *power distribution system* and mounts motors and electrical equipment in each vehicle. This improves acceleration and deceleration performance, shorting the time required between stations. Distribution of the equipment reduces the maximum axle weight of the vehicle and reduces the cost of the structure that supports it.

France and Germany adopted the *power concentration system* and installed locomotives on both ends of the train set. The advantage to this is that it is possible to operate on various electrification systems or non-electrified sections by exchanging the locomotive, and since the traction power is concentrated, the checking work of the vehicle is reduced.

In the past, the advantages and disadvantages of both systems were discussed, but the power distribution method became the mainstream in recent years. Even in France, which claimed the benefit of power concentration, also manufactures AGV with the power distribution system. One of the reasons is that the motors can be used not only for driving, but also for braking, and the distribution system can apply many powerful regenerative brakes.

(3) Safety Standards

There are two issues to discuss regarding safety standards; train collision loads and tunnel fire countermeasures.

Regarding collisions, vehicles are designed in Europe anticipating the collision load, which is useful in case of an accident in a low-speed operation section when a high speed train enters the conventional line. However, it could not respond to a train accident in the high speed section which occurred in Eschede, Germany. In Japan, since high speed trains do not operate on conventional lines and with improvement of signal security, it is not necessary to consider train collision load as the collision of trains is eliminated completely.

Regarding the countermeasure against the occurrence of a train fire in tunnels, in Europe, a twin single-track tunnel connected by communication tunnels is installed so that passengers can evacuate when a train stops in a tunnel due to a fire.[3]

Japanese countermeasures to deal with the fire in a dual-track tunnel are considered under the following concept, adopted from past experiences.

1) Rolling stock is made of flame-retardant materials and has doors separating the carriages.
2) The main idea is not to stop trains in the tunnel and to get the trains out of the tunnel right after the incident.
3) Exceptionally, the Seikan Tunnel with a length of 54 km has two fire-extinguishing facilities, and the train that is experiencing a fire would stop there, and there is a safe route for passengers to evacuate to ground level. This is based on the concept that it is better to stop the train that is on fire even in the tunnel, rather than running 5-6 minutes to go out of the tunnel which is longer than 20 km.
4) In case of a fire, the most important thing is the safety of passengers. For this purpose, the ventilation and lighting system is installed in all tunnels in preparation for a case where the train must stop in the tunnel due to a fire. It enables passengers to escape out of the tunnel through the central path, which is usually used for patrol and inspection (Width: 1 m, Depth: 1 m).

(4) The Concept of the High Speed Railway System

From the time the railway was founded in the UK and spread all over the world, adaptations have been made for the tracks, signals, power schemes, etc., according to the location of where the railway is. Similarly, high speed railway that began with the Shinkansen in Japan has been modified in the process of propagating to other countries.

The major characteristic of the Shinkansen is the high speed operation on a dedicated line. For this reason, the weight of the train was reduced to save the load on the structure and power consumption, optimizing the entire system of the high speed railway. This is an advantage with a railway isolated from the conventional railway. The high speed railway in Europe conducted service with conventional lines. It was adapted to the existing railway stations to lower construction costs. By adopting the locomotive system, it aimed to also operate in non-electrified

[3] If a train on fire stops in the tunnel, all trains in both directions are stopped not to disturb passenger evacuation and firefighting activities. Even if the bi-directional signaling system is equipped in twin tunnels like the one in Europe, the other tunnel cannot be used for train operation in such situations.

sections. Although these measures reduced construction costs initially, it caused complexity with the signaling system on the conventional lines and increase of axle load.

As described above, there are various angles when thinking about high speed railway systems. However, the general trend has shifted to the simplification and maximization of the use of a high speed railway, in consideration of the increase in passenger demand and progress of the construction of high speed lines dedicated to passengers in France and Germany.

In recent years, not only investment costs including the initial construction cost, but also the lifecycle cost including maintenance costs, are matters of concern in the development of a high speed railway. It is important to pay attention to the design of the structure and procurement of the vehicles.

1.2.2 Performance of High Speed Trains

The performances of major high speed trains in the world are shown in the following tables.

(1) Shinkansen

Table 1.3: Performance of Japanese Shinkansen

	Shinkansen		
	N700A	**E5**	**W7**
Line	Tokaido, Sanyo	Tohoku	Hokuriku
Opening (year)	2013	2011	2015
Gauge (mm)	1,435	1,435	1,435
Max. Speed (km/h)	300	320	260
Length of train set (m)	405	253	296.5
Train Set: Train set Power Car	14M2T Multiple Unit	8M2T Multiple Unit	10M2T Multiple Unit
Characteristics: Truck	Non-articulated	Non-articulated	Non-articulated
Coupling of train sets	Unable	Acceptable	Unable
Capacity: Special Seat First Class (person) Second Class (person) Train set Total	 200 1,123 1,323	18 55 658 731	18 63 853 934
Width of Car Body (mm)	3,360	3,350	3,380
Trainset: Tare weight (t) Gross weight (t)	NA NA	454.3 496	340 NA
Axle Load (t)	NA	NA	Less than 13
Feeding System	AC 25 kV 60 Hz	AC 25 kV 50 Hz	AC 25 kV 50 Hz AC 25 kV 60 Hz
Rated output of trainset (kW)	17,080	9,600	12,000
Note	Constant Speed Cruise Control		Steep Slope of 30/1000

Source: "Railways in the World" Diamond Co. (2015)

(2) TGV

Table 1.4: Performance of French TGV

	TGV		
	TGV-2N2	**TGV-POS**	**AGV/ETR575**
Line	France, Switzerland, Germany, Spain	France, Switzerland	Italy
Opening (year)	2011	2007	2012
Gauge (mm)	1,435	1,435	1,435
Max. Speed (km/h)	320	320	300
Design Speed (km/h)	350	350	360
Length of train set (m)	200	200	202
Train Set: Train set Power Car	2L8T Locomotive on Both Ends	2L8T Locomotive on Both Ends	12 Bogies (5 Motor Bogies) Multiple Unit
Characteristic: Coupling	Articulated	Articulate	Articulated
Coupling of train sets	Acceptable	Acceptable	Acceptable
Capacity: Special Seat First Class(person) Second Class (person) Trainset Total	 182 328 510	 110 250 360	19 143 288 450
Width of Car Body (mm)	2,896	2,904	3,000
Trainset: Tare weight (t) Gross weight (t)	390 NA	383 NA	374 398
Axle Load (t): Full passenger Average Passenger	17 NA	17 NA	16.5 NA
Feeding System	AC 25 kV 50 Hz AC 15 kV 162/3Hz DC 1.5 kV	AC 25 kV 50 Hz AC 15 kV 162/3Hz DC 1.5 kV	AC 25 kV 50 Hz DC 3 kV
Rated output of train set (kW)	9,280	9,280	7,500
Note	Double decker TGV Euro Duplex		NTV. italo

Source: “Railways in the World” Diamond Co. (2015)

(3) ICE

Table 1.5: Performance of German ICE

	ICE		
	ICE-3M	**Velaro D**	**AVES103**
Line	Germany, the Netherlands, Belgium	Germany	Spain
Opening (year)	2000	2013	2007
Gauge (mm)	1,435	1,435	1,435
Max. Speed (km/h)	320	320	300
Design Speed (km/h)	330	350	350
Length of train set (m)	200	200	250
Train Set: Train set Power Car	4M4T Multiple Unit	4M4T Multiple Unit	4M4T Multiple Unit
Characteristic: Coupling	Non-articulated	Non-articulated	Non-articulated
Coupling of train sets	Acceptable	Acceptable	Acceptable
Capacity: Special Seat First Class (person) Second Class (person) Trainset Total	 93 326 419	 93 333 426	50 103 264 417
Width of Car Body (mm)	2,950	2,924	2,950
Trainset: Tare weight (t) Gross weight (t)	435 465	454 NA	439 455
Axle Load (t): Full passenger Average Passenger	16 14.5	16 14.5	17 NA
Feeding System	AC 25 kV 50 Hz AC15 kV 162/3 Hz DC 3 kV DC 1.5 kV	AC 25 kV 50 Hz AC15 kV 162/3 Hz DC 3 kV	AC 25 kV 50 Hz
Rated output of train set (kW)	8,000	8,000	8,800
Note		Introduction to Eurostar and Turkey	

Source: "Railways in the World" Diamond Co. (2015)

1.2.3 Standards of High Speed Railways

The standards of the main high speed railways in the world are shown in the following tables.

(1) Japan

Table 1.6: Standards of Shinkansen

Line	Name	Tokaido	Tohoku	Hokuriku
	Section	Tokyo - Osaka	Tokyo - Morioka	Takasaki - Kanazawa
	Line Length (km)	515	496	356
Construction Period		1959-1964	1971-1982	1989-2015
Standard	Gauge (mm)	1,435	1,435	1,435
	Design Max. Speed (km/h)	210	260	260
	Max. Operating Speed (km/h)	270	320	260
	Minimum Curve Radius (m)	2,500	4,000	4,000
	Minimum Vertical Curve Radius (m)	10,000	15,000	15,000
	Cant Max. (mm)	200	180	200
	Allowable Cant Deficiency	90	60	90
	Maximum Grade (1/1000)	20	15	30
	Track Spacing (m)	4.2	4.3	4.3/4.2
	Vehicle Width (m)	3.4	3.4	3.4
	Design Load	NP-16	N-16/P-17	P-16
	Formation Width (m)	10.9	11.6	11.2/11.7
	Tunnel Cross Section (m^2)	63.5	63.4	Approx. 63
Structure	Earthwork (km)	274 (53%)	27 (5%)	23 (6%)
	Bridge and Viaduct (km)	173 (34%)	354 (71%)	168 (47%)
	Tunnel (km)	69 (13%)	115 (23%)	168 (47%)
Track	Structure	Ballast	Ballast/Slab	Slab
Feeding	Voltage and Frequency	AC25 kV 60 Hz	AC 25 kV 50 Hz	AC 25 kV 50 H/60 Hz
	Feeding System	AT	AT	AT
Contact Line	Catenary System	Heavy Compound	Heavy Compound	Simple
	Tension (kN)	53.9	53.9	39.2
	Sectional Area (mm^2)	500	500	260
	Span Length (m)	50	50	50
	Wave Velocity (km/h)	415	410	521/506
Signal	System	Cab Signal	Cab Signal	Cab Signal
	Train Control	ATC	ATC	ATC
	Train Detection	Insulated Track Circuit	Insulated Track Circuit	Insulated and None-insulated Track Circuit
	Reverse Direction Operation	Impossible	Impossible	Impossible
	Entry by Conventional Train	Impossible	Impossible	Impossible
Note		Passenger and Cargo (Only Design)	Passenger and Cargo (Only Design)	Passenger Only

Source: "Railways in the World" Diamond Co. (2015)

(2) France

Table 1.7: Standards of TGV

Line	Name	South East	Atlantic	Mediterranean
	Section	Paris - Lyon	Paris - Le Mans /Toulouse	Valence - Marseille
	Line Length (km)	410	284	250
Construction Period		1976-1983	1985-1990	1995-2001
Standard	Gauge (mm)	1,435	1,435	1,435
	Design Max. Speed (km/h)	300	300	350
	Max. Operating Speed (km/h)	300	300	300/200
	Minimum Curve Radius (m)	4,000	6,250	6,250
	Minimum Vertical Curve Radius (m)	25,000	25,000	25,000
	Cant Max. (mm)	180	180	180
	Allowable Cant Deficiency	85	60	65
	Maximum Grade (1/1000)	35	25	35
	Track Spacing (m)	4.2	4.2	4.8
	Vehicle Width (m)	2.9	2.9	2.9
	Design Load	17	17	17
	Formation Width (m)	13.6	13.6	14.2
	Tunnel Cross Section (m^2)	-	71	100
Structure	Earthwork (km)	405 (99%)	265 (93%)	220 (88%)
	Bridge and Viaduct (km)	5 (1%)	3 (1%)	17 (7%)
	Tunnel (km)	0 (0%)	16 (6%)	13 (5%)
Track	Structure	Ballast	Ballast	Ballast
Feeding	Voltage and Frequency	AC 25 kV 50 Hz	AC 25 kV 50 Hz	AC 25 kV 50 Hz
	Feeding System	AT	AT	AT
Contact Line	Catenary System	Simple	Simple	Simple
	Tension (kN)	34	34	45
	Sectional Area (mm^2)	215	215	266
	Span Length (m)	63	63	63
	Wave Velocity (km/h)	441	441	493
Signal	System	Cab Signal	Cab Signal	Cab Signal
	Train Control	TVM300	TVM300	TVM300
	Train Detection	None-insulated Track Circuit	None-insulated Track Circuit	None-insulated Track Circuit
	Reverse Direction Operation	Possible	Possible	Possible
	Entry by Conventional Train	Impossible	Impossible	Impossible
Note		Passenger Only	Passenger Only	Passenger Only

Source: “Railways in the World” Diamond Co. (2015)

(3) Germany

Table 1.8: Standards of ICE

Line	Name	NBS		
	Section	Manheim - Stuttgart	Hanover - Wurzburg	Koln - Frankfurt
	Line Length (km)	99	327	177
Construction Period		1976-1991	1979-1991	1995-2002
Standard	Gauge (mm)	1,435	1,435	1,435
	Design Max. Speed (km/h)	300	300	330
	Max. Operating Speed (km/h)	280	280	300
	Minimum Curve Radius (m)	4,670	4,670	4,000
	Minimum Vertical Curve Radius (m)	22,000	22,000	11,500
	Cant Max. (mm)	160	160	160
	Allowable Cant Deficiency	100	100	150
	Maximum Grade (1/1000)	12.5	12.5	40
	Track Spacing (m)	4.7	4.7	4.5
	Vehicle Width (m)	3.1	3.1	3.1
	Design Load	19.5	19.5	16
	Formation Width (m)	13.7	13.7	12.1
	Tunnel Cross Section (m^2)	82	82	92
Structure	Earthwork (km)	64 (65%)	177 (54%)	126 (75%)
	Bridge and Viaduct (km)	5 (5%)	30 (9%)	6 (3%)
	Tunnel (km)	30 (30%)	120 (37%)	47 (22%)
Track	Structure	Ballast	Ballast	Ballast
Feeding	Voltage and Frequency	AC 25 kV 162/3 Hz	AC 25 kV 162/3 Hz	AC 25 kV 162/3 Hz
	Feeding System	Direct	Direct	Direct
Contact Line	Catenary System	Deformation Y Simple	Deformation Y Simple	Deformation Y Simple
	Tension (kN)	30	30	48
	Sectional Area (mm^2)	190	190	240
	Span Length (m)	65	65	70
	Wave Velocity (km/h)	427	427	569
Signal	System	Cab Signal	Cab Signal	Cab Signal
	Train Control	LZB	LZB	LZB
	Train Detection	None-insulated Track Circuit	None-insulated Track Circuit	None-insulated Track Circuit
	Reverse Direction Operation	Possible	Possible	Possible
	Entry by Conventional Train	Possible	Possible	Possible
Note		Passenger and Cargo	Passenger and Cargo	Passenger and Cargo

Source: "Railways in the World" Diamond Co. (2015)

(4) Asia

Table 1.9: Standards of HSR in Asia

Line	Country	Korea	Taiwan	China
	Section	Seoul - Busan	Taipei - Zuoying	Beijing - Shanghai
	Line Length (km)	412	345	1,318
Construction Period		1992-2010	1999-2006	2008-2011
Standard	Gauge (mm)	1,435	1,435	1,435
	Design Max. Speed (km/h)	350	350	380
	Max. Operating Speed (km/h)	300	300	350
	Minimum Curve Radius (m)	7,000	6,250	9,000
	Minimum Vertical Curve Radius (m)	25,000	25,000	25,000
	Cant Max. (mm)	180	NA	180
	Allowable Cant Deficiency	90	NA	80
	Maximum Grade (1/1000)	15	25	20
	Track Spacing (m)	5.0	4.5	5.0
	Vehicle Width (m)	2.9	3.4	NA
	Design Load	17	25.5	20
	Formation Width (m)	14.0	13.0	13.8
	Tunnel Cross Section (m^2)	107	90	100
Structure	Earthwork (km)	111 (27%)	33 (10%)	1,140 (87%)
	Bridge and Viaduct (km)	112 (27%)	247 (72%)	162 (12%)
	Tunnel (km)	189 (46%)	65 (19%)	16 (1%)
Track	Structure	Slab/Ballast	Slab/Ballast	Slab/Ballast
Feeding	Voltage and Frequency	AC 25 kV 60 Hz	AC 25 kV 60 Hz	AC 25 kV 50 Hz
	Feeding System	AT	AT	AT
Contact Line	Catenary System	Simple	Heavy Compound	Deformation Y Simple
	Tension (kN)	34	NA	NA
	Sectional Area (mm^2)	215	NA	NA
	Span Length (m)	63	NA	NA
	Wave Velocity (km/h)	441	NA	NA
Signal	System	Cab Signal	Cab Signal	Cab Signal
	Train Control	ATC	ATC	CTC3
	Train Detection	None-insulated Track Circuit	Insulated Track Circuit	None-insulated Track Circuit
	Reverse Direction Operation	Possible	Possible	Possible
	Entry by Conventional Train	Impossible	Impossible	Possible
Note		Passenger Only	Passenger Only	Passenger Only

Source: “Railways in the World” Diamond Co. (2015)

1.2.4 Standards of High Speed Railways in Vietnam

The recommended standards for high speed railways in Vietnam and the reasons are listed below. Details are described in Chapter 3.

Table 1.10: Recommended Standards for HSR in Vietnam

	Specifications		Reason
1	Design Maximum Speed	350 km/h	Common in the world.
2	Maximum Service Speed	320 km/h	Maximum speed for Japan/ Europe
3	Design load	P-16	Reduction of the construction cost as a passenger dedicated line; Same load as with Shinkansen considering the flexibility of vehicle selection.
4	Track Spacing	4.3 m	Smaller and more economical than HSR in Europe; Experience in Shinkansen.
5	Minimum Curve Radius	6,000 m	Consistent with the design maximum speed
6	Cant Maximum	180 mm	Safety and riding comfort, same with Shinkansen.
7	Steepest Gradient	15/1000	Harmonization between the 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 structure for possible subsidence, Slab in tunnel and viaduct for reduction of maintenance.
9-1	Rail	60 kg/m	Reduction of maintenance by heavy rail; Experience in Shinkansen.
9-2	Turnout	#18	Reduction of cost and track maintenance; Experience in Shinkansen.
9-3	Ballast Thickness and Track Slab	300 mm/ flame-shaped slab	Experience in Shinkansen; Reduction of cost for both construction and maintenance.
9-4	Sleeper	43 sleepers/25 m	Experience in Shinkansen.
10	Cross Section of Tunnel	64 m^2	Experience in Shinkansen; Smaller and cheaper than that of China and Europe
11	Signal	VHSR-ATC Digital Radio ATC	Improved ATC corresponding to two-way operation; the prototype is attached for Tohoku Shinkansen, and the confirmation test is scheduled
12	Communication	Digital Train Radio	Continuous and stable communication by LCX.
13	Power	AC 25 kV	Experience in Shinkansen; Cost reduction by long substation interval using high voltage.

Source: JICA Study Team

1.2.5 Construction Cost of High Speed Railway

(1) Factors Affecting Construction Cost

The construction cost of a high speed railway depends on the environment and technology. The former includes noise regulation standards, earthquake resistance measures, ground conditions, etc. The latter includes dimensions of the structure, vehicles, specifications of structures, etc. These are summarized in the below table.

Table 1.11: Factors Affecting Construction Cost of a High Speed Railway

Factors		Impact on construction cost
Environment	Noise Regulation Standard	Strict noise regulation standards require a high soundproof wall. The wall is supported by an expensive foundation.
	Earthquake Resistance measures	A strong (and expensive) structure is necessary to endure a big earthquake.
	Ground Condition	On soft ground, foundation structures such as piles become expensive.
Technology	Dimension of Structure	Construction costs increase if the track spacing and the formation width are large.
	Axle Load	Heavy axle load requires expensive reinforced structures.
	Tunnel	Long tunnels are expensive. Twin single-track tunnel is more expensive than one double-track tunnel.
	Viaduct	Generally, a beam structure requires more expensive construction materials than a rigid-frame structure.

Source: JICA Study Team

Among these factors, the ones that mainly impact construction costs are technical. The reason is that the method of adapting to environmental conditions such as noise and soil conditions do not fluctuate much and the influence on construction cost is similar for any HSR.

(2) Construction Cost of Viaduct

As a typical example of a Japanese viaduct, an axle load of 11.4 t, formation width of 11.2 m, design seismic intensity of 1,700-gal, pile length of 40 m and structure length of 70 m (Ramen viaduct 60 m, connection beam with other ramen 10 m) has been considered. The volume of concrete for the whole structure is 1,303 m^3, including a slab of 365 m^3 (28% of the entire volume). The Study Team compared the above structure with an axle load of 19.5 t and formation width of 14.2 m, which is common in Europe and China.

1) Axle Load

The axle load acts on the longitudinal beam which supports the floor slab. According to the comparative design, the beam height increases by 0.2 m from 1.4 m to 1.6 m. As there are two beams of 80 cm width, the concrete volume increases 0.32 m^3/m (=0.2*0.8*2). For the structure of 70 m, the concrete volume increases by 2 % (=0.32*70/1,303).

2) Formation Width

When the formation width is different, the volume of concrete for slab differs by 27% (= (14.2-11.2)/11.2).

The slab concrete is 28% of the entire volume as mentioned above. Therefore, the difference in the volume of concrete is 8% (= (0.28*0.27).

3) Total

Assuming the construction cost is proportionate to the concrete volume, the difference of construction cost in total is 10% (=2+8).

(3) Construction Cost of Tunnel

The breakdown of tunnel construction cost is as follows; net construction costs 76%, site management fees 17%, and general administrative expenses 7%. Net construction costs are made up of material costs, labor costs, machine losses and others; and each account for 40%, 20%, 40% respectively, which is proportional to the cross-sectional area of the tunnel.

As a typical example of a Japanese tunnel, a double track tunnel with a cross-sectional area of 62.8 m^2 has been considered.

In comparison with the above example, a Chinese double track tunnel has a cross-sectional area of 107 m^2. The cross-section ratio is 107/62.8=1.70.

In Europe, there are many types of tunnels such as double-track tunnels with a cross-sectional area of 70 -100 m^2 and twin single-track tunnels with cross-section areas of 70 m^2 each. Since the cross-sectional area of the double-track tunnel is not much different from that of the Chinese, we will consider a twin single-track tunnel as "European" design and compare with the Japanese design. For the twin single-track tunnel, the cross-section ratio is 2.23 (=70*2/62.8). Here, it has been assumed that the construction cost is proportionate to the cross-sectional area.

When a high speed train passes through the tunnel, a micro pressure wave may be generated, causing a sound impact. To prevent this, a *tunnel entrance hood* is equipped at the tunnel entrance. This need depends on the cross-sectional area, length, and track structure of the tunnel. It is applied not only in Japan but also in Europe and China.

(4) Construction Cost of Earth Works

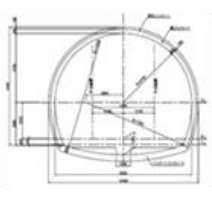
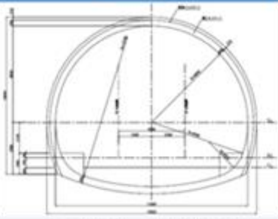
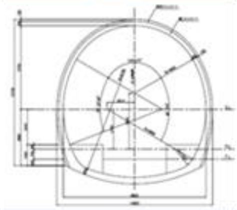
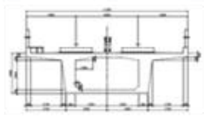
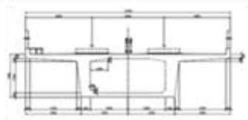
There is a 797 km stretch of soil structure section where the construction cost depends on the formation width. Assuming the embankment height is 5 m, the Japanese design is 15% cheaper than others.

(5) Cost Comparison when Applied to Vietnam

The total length between Hanoi and Ho Chi Minh is 1,541 km, with the viaduct length of 886 km, tunnel length of 178 km and soil structure length of 457 km. By multiplying the unit cost of structures, the influence of the design can be is calculated.

The cross-section of the compared tunnel and elevated bridge is shown in the following table.

Table 1.12: Comparison of Cross Sections

		Japan	China	Europe
Tunnel	Sectional view			
	Sectional area	Double Track 63m²	Double Track 107m²	Single Track 70m²X 2 =140m²
Viaduct	Sectional view			
	Formation width Axle load	11.2 m 11.4 t	14.2 m 19.5 t	

Source: JICA Study Team based on "Construction of high speed railways abroad" (Ministry of Land, Infrastructure, Transport and Tourism, 2010)

1.3 Role Sharing Between HSR and Conventional Lines

1.3.1 Summary of the Previous Survey

(1) Improvement Levels for Existing Lines

In the Previous Survey (JICA Survey conducted in 2013), the following four improvement levels for the existing railway were examined together with the HSR along the North-South Corridor.

Table 1.13: Improvement Levels of Existing Lines

Level	Concept
A1	• Minimal improvements to ensure safe operation (ongoing and committed projects) • Maximum Operating Speed: 90 km/h (Travel Time: 29.1 h Hanoi – HCMC) • Line Capacity: 32 trains/day/both-direction
A2	• Maximization of existing single-track transportation capacity • Maximum Operating Speed: 90 km/h (Travel Time: 25.41 h Hanoi – HCMC) • Line Capacity: 50 trains/day/both-direction
B1	• Double tracking with meter gauge • Maximum Operating Speed: 120 km/h (Travel Time: 15.6 h Hanoi – HCMC) • Line Capacity: 116 trains/day/both-direction
B2	• Double tracking with standard gauge • Maximum Operating Speed: 150 km/h (Travel Time: 12.7 h Hanoi – HCMC) • Line Capacity: 122 trains/day/both-direction

Source: Previous Study (JICA, 2013)

(2) Transport Demand

In the Previous Study ("Study for the Formulation of High Speed Railway Projects in Vietnam" JICA, 2013), the railway demand in 2030 is assumed as shown in the table below. The biggest demand is the Hanoi – Thanh Hoa section in the north, 24 passenger trains and 56 freight trains, totaling 80 trains. On the other hand, the current number of trains operated is 32 / day.

Table 1.14: Demand Forecast in 2030 (Number of Trains/Day)

Section		Conventional		HSR
		Passenger	Freight	
North	Hanoi - Thanh Hoa	24	56	101
	Thanh Hoa - Vinh	20	54	92
Central	Vinh - Hue	21	53	85
	Hue - Da Nang	21	51	91
	Da Nang - Nha Trang	23	45	110
South	Nha Trang - Phan Thiet	22	26	111
	Phan Thiet - Ho Chi Minh	24	27	108

Source: Previous Study (JICA, 2013)

(3) Line Capacity and Investment Required

In the Previous Study, the measures to increase the capacity of conventional lines are summarized in the four levels listed in the table below.

Table 1.15: Overview of Improvement Levels for Conventional Lines

Improvement Levels		A1	A2	B1	B2
Track	Single/Double	Single	Single	Double	Double
	Electrification	None	None	None	Electrified
	Gauge (mm)	1,000	1,000	1,000	1,435
	Min. curve radius (m)	100 (existing)		800	1,200
	New stations		18		
Max. Speed (km/h)	Passenger	90 (existing)	90 (existing)	120	150
	Freight (Bulk)	60 (existing)	60 (existing)	70	80
	Freight (Container)				120
Facilities	Alignment Improvement		Hai Van, Khe Net, Hoa Duyet - Than Luyen *substandard curvatures in B1 and B2		
	Effective Track length (m)	350 (existing)	450	450	450
Train/day (both directions)	Passenger	22	28	40	42
	Freight	10	32	76	80
	Total	32 (existing)	50	116	122
Preliminarily Estimated Cost (USD million)		Removed			

Source: Previous Study (JICA, 2013)

(4) Direction for Improvement of Transport Capacity

By comparing transport demand and transport capacity and considering the required investment amount, the direction of the improvement of the railway in the North-South Corridor was directed as follows.

1) The high speed railway shall be constructed with a new line dedicated to passengers, and the completion of the whole line is a long-term target.
2) The improvement of the existing line shall be completed before 2020-25 in the direction shown in Level A2, which maximizes the line capacity of the single-track line, responding to passenger and cargo demands during this period.
3) In sections where demand is high, it may be possible to install double-tracking shown in Level B1. Freight transport demands and local passenger transport demands would require further consideration at appropriate times.

1.3.2 This Survey

(1) Existing Line after the Opening of HSR

As in the previous survey, it was assumed that the demand for railway, passengers and cargoes of the existing line will continue to increase (see Chapter 2). In Japan, after the opening of the Shinkansen, demand for the concurrent conventional lines has dropped, the profitability has deteriorated, and the abolition of existing lines has been discussed. However, there is no such concern for the existing line in Vietnam. Therefore, the coordination between high speed railway and existing lines for the improvement of transport capacity is considered to be the challenge.

(2) Improvement of Existing Line

The Table 1.15 indicates that level A2 increases the line capacity to 50 trains/day by the installation of 18 new stations, also improving signals and others. As a subsequent measure, level B1 is listed, which makes the whole line double track. However, phased improvements are useful, such as the development of new stations and signal improvements from the low capacity sections.

In order to increase the line capacity more effectively, the following policy is preferable:

- Actively and strategically induce passenger demand to high speed railway and allocate the line capacity produced for freight transport.
- Maximize the utilization of equipment invested to increase line capacity.

The table below shows the idea of demand forecast and line capacity. Estimated demand in 2030 is 24 passenger trains/day and 56 freight trains/day, total of 80 trains/day. But if 12 trains for passengers can be induced to high speed railway, the line capacity required for the conventional line will be reduced to 68 trains/day. This reduced capacity is expressed as Target capacity. As a measure for satisfying Target capacity, a part of the menu included in level B1 shall be executed.

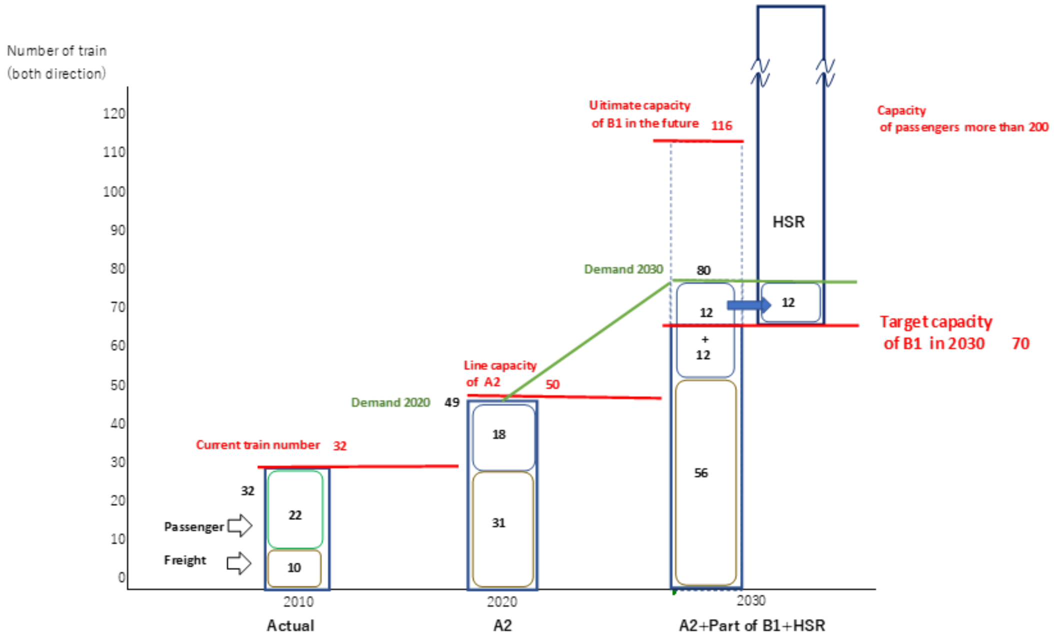
Table 1.16: Demand Forecast and Track Capacity

Unit: trains/day/both directions

	Demand			Line Capacity			
Year	**Passenger**	**Freight**	**Total**	**Level**	**Passenger**	**Freight**	**Total**
2010	22	10	32	A1	22	10	32
2020	18	31	49	A2			50
2030	24	56	80	A2 + partially B1	12	56	68
				HSR	12		12

Note: HSR line capacity in 2030 is more than 200
Source: Previous Study (JICA, 2013)

The following figure shows the concept. As an increased number of passengers are induced to high speed railway (which will commence in 2030), the load on conventional lines will decrease. As a result, it would allow the delay of investment in level B1. The subject is the method of encouraging passengers to use high speed railway.



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

Figure 1.8: Target Capacity

1.3.3 Induction to High Speed Railway

If passenger demand can be shifted to high speed railway, the number of passenger trains on conventional lines could be decreased and the number of trains to be allocated to freight trains could be increased. This would also contribute to the operating income of high speed railway as a result. The specific measures are described in the table below.

Table 1.17: High Speed Railway Usage Promotion Measures

Reflecting needs of passengers ● Implementation of frequent revisions of train diagram (grasping demand and analysis)
Aggressively responding to needs ● Discounts ● Planning with other organizations ● Public relations
Reference: Major discount ticket for Shinkansen ● For specific time zones ● For specific periods / seasons ● For specific sections ● For specific users ● For transit passengers ● Commercialization with other agencies (hotels, car rental, etc.)

Source: JICA Study Team

Since the high speed railway is operated on a double-track line, it is easier to draw a train diagram responding to flexibly in demand far more than that of a conventional single-track line. In other words, it is possible to collect many passengers by grasping the demand accurately and reflecting it in the train diagram. For that purpose, continuous collection and analysis of the sales performance data and regular investigation of user intentions shall be conducted. This data would indicate the trends in demand and would clarify the improvements necessary on the train diagram.

The items that passengers are most interested in are the departure and arrival times of the first and the last train and the operating section, the passage stations of the express train and the stopping stations. It is greatly effective to revise the train diagram regularly and to operate extra trains using the reserved train set.

JR revises their train diagram every year, which contains the plans of many extra trains. The basis of the plan is accumulated information such as demand for each season, the day of the week, time zone, etc., which is reflected in the daily operating diagram. In addition, various discounts, collaborative planning with accommodation facilities, and advertisement and publicity also have a significant effect on high speed railway demand. Examples of major discount tickets on the Shinkansen are shown in the above table. It focuses on increasing the usage in time zones and sections with low demand, as well as those that aimed at the convenience of transit from conventional lines to Shinkansen and those for commuters.

1.3.4 Priority in Level B1

The basics of level B1 is the increase in line capacity due to the partial track doubling of conventional lines, which is conducted in phases, at the bottleneck sections. Normally, a bottleneck section is the section where the time required between stations is long, and in many cases, where the distance between stations is long. The table below shows the situation of the curve of the conventional lines. The sum of the curve section and straight section (which has a radius of 1,200 m or more) accounts for 78.9% of the entire section. In these sections, it is considered that there will be no large-scale modification of track alignment and that although there may be partial track additions or station installations, there is only a small possibility of major renovations required.

Table 1.18: Curve in Conventional Lines

<table>
<tr><th>Radius</th><th>No.</th><th>Length (km)</th><th colspan="2">Ratio (%)</th></tr>
<tr><td>R≤300 m</td><td>267</td><td>38.8</td><td>2.2</td><td rowspan="3">21.1</td></tr>
<tr><td>300 m≤R<800 m</td><td>841</td><td>214.7</td><td>12.4</td></tr>
<tr><td>800 m≤R<1,200 m</td><td>421</td><td>110.3</td><td>6.4</td></tr>
<tr><td>1,200 m≤R</td><td>232</td><td>31.2</td><td>1.8</td><td rowspan="2">78.9</td></tr>
<tr><td>Straight</td><td></td><td>1,331.10</td><td>77.1</td></tr>
<tr><td>Total</td><td></td><td>1,726.10</td><td>100.0</td><td>100</td></tr>
</table>

Source: Previous Study (JICA, 2013)

Also, revision of the train diagram increases the line capacity through the consideration of maximizing the capacity of each piece of equipment, such as the track alignment, signaling, turn outs and rolling stock. Furthermore, it is also important to improve the transportation system drastically, including the installation of freight stations and containerization. These would also contribute in increasing the line capacity, such as stoppage time reduction of the cargo train and loading time.

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

1.4.1 Overview

In this section, the validity of freight train operation on the high speed railway line between Hanoi – Ho Chi Minh, which is planned as a passenger only railway, will be considered. There are only a few cases of freight train operation on a high speed line from a global point of view. The reasons are as follows:

1) Operating a freight train with a large speed difference from a high speed passenger train reduces the number of trains on the line.
2) Due to the draft caused by high speed trains, a falling-load accident may occur on the freight wagon on the opposite track. The load may scatter or fall, and it could cause a serious accident.

In this study, these issues and a feasible operation method have been studied. The required equipment and investment amount when carrying out freight transportation on the high speed railway in Vietnam have been considered from the following viewpoints:

1) Examples from other foreign countries
2) The concept of freight transportation on the HSR line
3) Equipment for freight transport
4) Rolling stock
5) Train diagram
6) Required investment

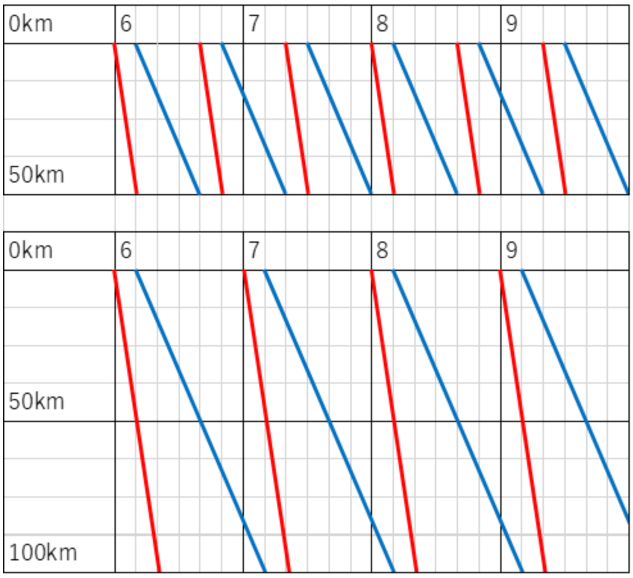
1.4.2 Technical Issues

(1) Reduction in the Number of Operable Trains with a Large Speed Difference

High speed passenger trains (of 300 km/h) and freight trains (of 100 km/h) operated alternately in the same direction in the sections of 50 km and 100 km between stations are considered.

The high speed passenger train arrives to the next station in 50/300 * 60 = 10 minutes and the freight train takes 50/100 * 60 = 30 minutes. The time interval between trains is 10 minutes.

The figure shows the train diagram; the upper part shows the 50 km station distance and the lower part shows the 100 km station distance.



Note: Red and blue line indicate high speed train and cargo train respectively.
Source: JICA Study Team

Figure 1.9: Operable Number of Trains

When the station distance is 50 km, a total of 6 trains (3 passenger and 3 freight) are operable in 2 hours; that is 3 trains (1.5 passenger and 1.5 freight) per hour. In the case of 100 km between stations, one passenger train and one freight train are operable per hour.

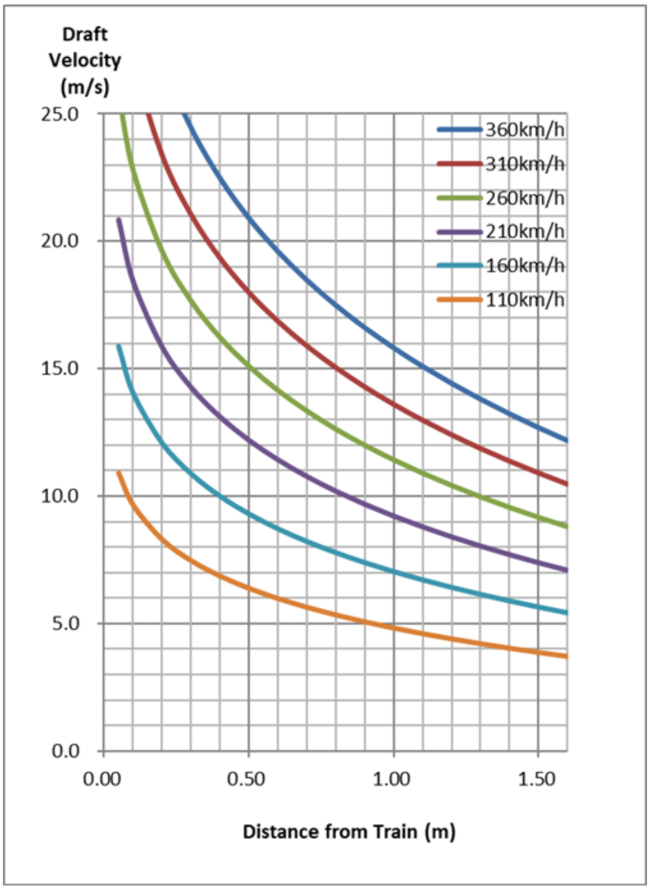
The north and south high speed railway in Vietnam assumes 23 stations in the section of 1,541 km, with an average distance between stations of 70 km.

In order to increase the number of operable trains, the distance between stations must be shortened by installing more stations so that the passenger trains can bypass freight trains.

If only the number of trains is increased, the easiest way is to lower the speed of the high speed passenger train, but this loses the effect of the high speed railway itself.

(2) Influence of Train Draft Caused by High Speed Passenger Trains

When a high speed train passes, it generates a strong wind around it. This wind is called the train draft. The train draft increases as the train nose approaches, and at the nose, the wind direction is the same as the train's traveling direction. The peak of the train wind occurs at the time of passing the front part of the train and at the time of passing through the tail part. When passing through the front part, the wind speed increases rapidly, and when passing through the tail part, there is sustained variation. The train draft and pressure fluctuation are strong in the tunnel sections.



Source: Kikuchi, K., Kajiyama, H., Endoh, H. (2012). Wind Induced by Passing Train. *Wind Engineers*, JAWE, Vol. 37, No. 3 (No. 132) 198-203.

Figure 1.10: Train Draft

The train draft caused by high speed trains may affect the load on freight wagons; if the load drops, it would lead to a catastrophe. This issue is also related to the reliability of containers loaded on freight trains. The railway operator inspects and maintains the rolling stock, but maintenance and management of the container is the obligation of the owner. Therefore, railway operators are in a position of not having control over the containers. As a solution to this problem, a transportation system that pushes a container into a wagon that covers the surroundings is required.

(3) Experience in other Countries

The following table shows the aspects of freight transportation on high speed railway lines in foreign countries

Table 1.19: Concept of Freight Transportation on High Speed Railways

Country (Line)	Current situation		Background
	Operation Speed	Safety measures	
Germany (Neu Bau Strecke)	ICE High-speed 250-300km/h IC Locomotive 200km/h Freight 120km/h Parcel IC 160km/h	• Passenger trains run during the daytime, and freight trains run at night. • Train dispatchers control signals getting the information through train detection system.	• There is a law which prohibits the passing by operation relying only on human attention. • Accidents of freight train such as fire and falling cargo are considered to be most dangerous.
France (Ligne a Grande Vitesse)	TGV 300-320km/h TGV La Post 270km/h	• Only La Post runs which has same weight and speed with TGV.	• Train operation with speed difference decreases the line capacity. • Heavy freight train increases track maintenance work unless speed is reduced.
Italy (Direttisima)	Trenitalia/NTV 250-300km/h Freight 90-120km/h	• Monitors are installed to check freight trains such as loads, door of rolling stock, possible fires, and temperature of axles etc.	• Only express cargo trains are allowed to operate on high-speed line.
China	CRH 250-350km/h	• N/A	• There are some sections where freight trains are designed to run on the line at speeds exceeding 250 km/h.
Japan	Shinkansen 260-320km/h	• Shinkansen reduces its speed to less than 140km/h in the Seikan tunnel.	• Almost all sections of the high-speed line are for passenger dedicated service • However, the Seikan Tunnel, which connects Honshu and Hokkaido, the Shinkansen and the conventional line must share the track.

Source: JICA Study Team

As shown in the table above, Japan and France have high speed lines exclusively for passengers and no freight trains. In contrast, Germany and Italy are running passenger trains and freight trains on the same track. However, for these reasons, these countries also divide the operation time zone; passenger trains in the daytime, freight trains in the nighttime. In all cases, cargo trains and high speed trains do not pass by each other. Furthermore, in Germany, it is prohibited by law to rely solely on human attention to prevent mistakes on passenger trains and cargo trains. In Germany, further hardware countermeasures are taken, such as a system that displays mechanical warnings at the command office.

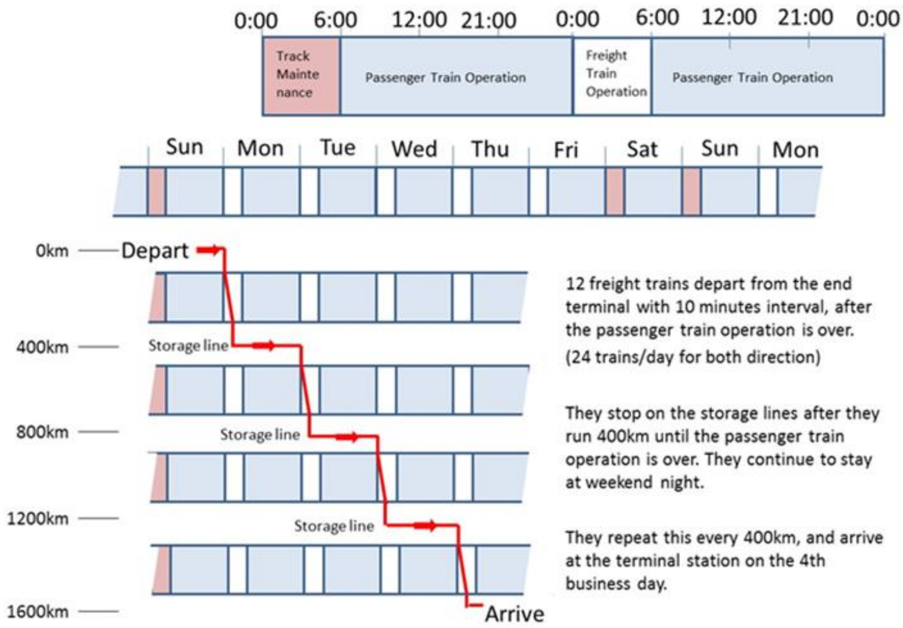
1.4.3 Application to High Speed Railway in Vietnam

(1) The Concept of Freight Transportation on the High Speed Line

From the viewpoint of safety when operating passenger trains and freight trains on the high speed railway line, the following assumptions are made for the operation of freight trains on the high speed railway in Vietnam.

From the viewpoint of safety when operating cargo trains on the high speed railway line, the following conditions shall be set for the operation of freight trains:

1) Freight trains are not operated during passenger train service hours.
2) The passenger trains are operated 18 hours from 6 o'clock in the morning to 24 o'clock, and the freight trains are operated 6 hours from 0 o'clock to 6 o'clock.
3) On Saturdays and Sundays, cargo trains are not operated due to track maintenance. That is, the operation of freight trains is limited from Monday to Friday night.
4) Assume that the speed of the freight train is 100 km/h.
5) The freight train is a dedicated container train.



Source: JICA Study Team

Figure 1.11: Image of Freight Train Operation

According to this premise, the freight trains travel 400 km at night, stops on the storage line, is bypassed by the passenger trains, and after 24 o'clock the next day proceeds again for 400 km, and stops again at next storage line. This shall be repeated for the operation of 1,541 km. As a result, the freight train leaving the Hanoi area will arrive in the Ho Chi Minh area over three nights and four days. Because the stoppage time in the middle is long, the average speed from the first station to the last station is about 20 km/h, which is not so different from that of the current operating speed of the conventional line.

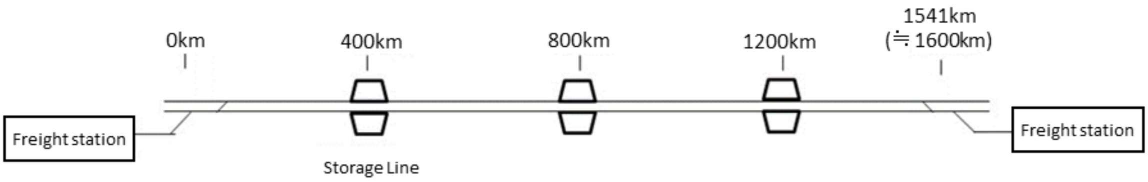
With this operating method, if the train operating interval is 10 minutes, 12 freight trains are operated in one day. The facilities necessary for the freight trains are cargo stations in Hanoi and Ho Chi Minh districts and three storage lines at 400 km intervals. Electric locomotives, including spares, are 102 electric locomotives, 8 diesel locomotives for shunting, and 2,424 cars for containers.

Points to be noted for safe operation are as follows:

1) Confirm that the weight of the container and the load are not biased, so as not to exceed the design conditions of the track. Also, check that the container doors are properly locked to prevent cargo from falling.
2) Upgrade the maintenance of locomotives and freight cars to the same level as the high speed passenger trains, so that there are no drops of brake shoes or the like and breakage of axles.
3) The maximum operating speed of freight trains is 120 km/h to 160 km/h in the world because of the characteristics of cargo trains which locomotives pull heavy freight wagons. In the case study, the scheduled speed is assumed at 100 km/h, so that the distance that can be driven overnight is around 400 km. And during the daytime when the passenger trains are operated, cargo trains are stopped on the storage lines that are set at every 400 km.

(2) Freight Transport Equipment

In this section, it is assumed that the demand for cargo transport is only between Hanoi and Ho Chi Minh, and all are direct trains with no intermediate handling. Both Hanoi and Ho Chi Minh are assumed to have one freight station for container handling with an inspection and repair facility. Also, storage lines shall be installed every 400 km. The arrangement of these facilities is shown in the following figure.



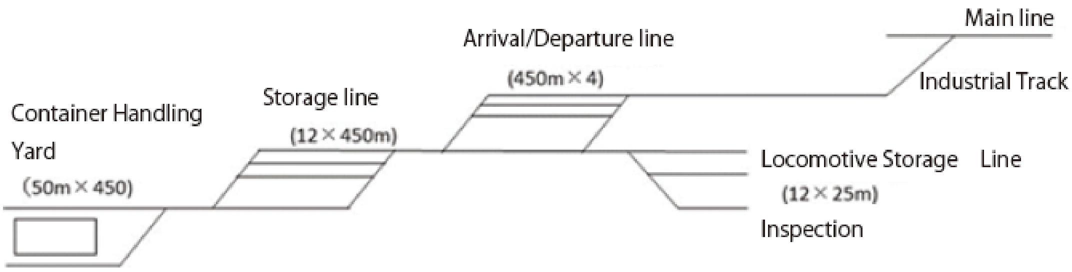
Source: JICA Study Team

Figure 1.12: Arrangement of Freight Facilities

The specifications for the freight facilities are assumed as follows:

1) The effective track length of freight equipment shall be 450 m, with the future high speed passenger train in mind.
2) Freight trains shall operate at 10-minute intervals, with 12 trains per section/ per night/ per direction. Therefore, 12 storage lines are required.
3) At the freight stations, a container handling equipment with rolling stock inspection facility shall be installed.
4) The electrified section is assumed to be from the main line to the arrival/ departure line. Other lines shall not be electrified. This is to secure the safety of cargo handling works.

The track alignment of a freight station is shown below.



Source: JICA Study Team

Figure 1.13: Freight Station Track Alignment

The container handling work is assumed as follows:

1) After the arrival of a train, it is moved to the arrival/ departure line, disconnected from the locomotive, and waits until the handling line becomes available.
2) Engines are transferred to the locomotive storage line and are inspected.
3) When the container handling line becomes available, container cars are moved to the handling line by the shunting locomotive.
4) On the handling line, the unloading and loading of containers is conducted using lifts.
5) After completion of the loading work, it is moved to the storage line by the shunting locomotive and waits until the arrival/ departure line is available.

6) When the arrival/ departure line becomes available, the locomotive is connected and moves to the arrival/ departure line as a train set.
7) The train set departs at the predetermined time.

(3) Rolling Stock

The freight train on the high speed railway line shall be a container cargo transport by an electric locomotive, and the vehicle shall conform to the standards assumed for high speed railways. Specifically, it shall be a vehicle that meets the following requirements:

1) It enables a schedule speed of 100 km/h
2) Maximum axle weight shall be within 17 tons for locomotives and freight cars
3) It can climb 15‰

Locomotives that meet the above requirements and have standardized on the EH 800 that are used in the Japanese Seikan Tunnel are assumed here. The specifications of the locomotive are shown below.

Table 1.20: Rolling Stock for Freight Transportation

Locomotive	EH800 for Seikan, Gauge change and output enhancement	**Container wagon**	Marine container wagon for standard gauge remodeled from #200
Length	25 m (twin body, 8 axis)	**Length**	15 m
Power	4,800 kW (120% of EH800)		
Axle Load	17 t	**Max. Axle Load**	16.25 t (with 2 × 20 Ft container)
Starting Tractive Effort	412 kN		
Total Weight	136 t	**Maximum weight**	65 t (tare weight: 17 t)
Remark	The full weight of Container	20 Ft.: 24 t, 40 Ft: 30.48 t	

Source: JICA Study Team

The reason why the axle weight of the locomotive is set to 17 tons (one ton heavier than the proposed axle load of HSR) is that this is the minimum requirement for the traction of a heavy freight train. As a result, this will affect the cost of the structure.

The maximum container weight is 30.48 tons for both 20- and 40-feet ISO standard containers. In this case, two 24-ton containers on one freight wagon was assumed, which aims to increase the transport efficiency of the railway. This is balanced with the axle weight of the locomotive. When the container weight is more than 24-tons, one container shall be loaded on the freight car.

One freight train consists of one locomotive and 24 container cars. The total length of the formation is 385 m (410 m when it is doubled as a locomotive in relief and forwarding, etc.). During operation as a train set, the formation is fixed. The reason why 24 freight cars is assumed is because it would be able to accommodate as many wagons as possible and to stop on the sub-main line of the nearest passenger station when a vehicle breakdown occurs. Connection with another locomotive is also assumed. Therefore, even if the train stops on a steep slope of 15‰; the locomotive has the power to get the train set moving. This allows the train set to travel on all high speed railway lines. However, it is necessary to limit the total container load including the container's weight to 1,000 tons.

Source: JR West[4]

Figure 1.14: EH800 for Seikan Tunnel

Source: Kawasaki Heavy Industry[5]

Figure 1.15: Container Car #200

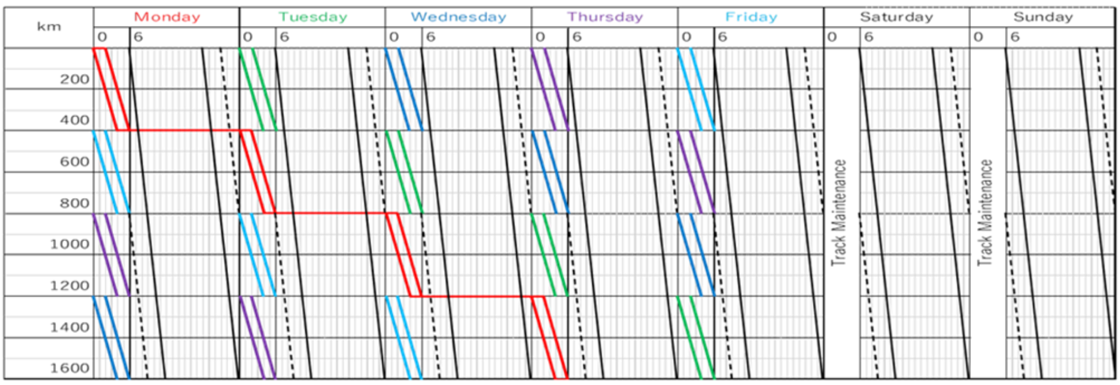
(4) Train Diagram[6]

The following figure shows a weekly schedule of freight trains. The train departing from Hanoi at 0 o'clock Monday arrives at Ho Chi Minh in over 76 hours (3 days and 4 hours). On Saturday and Sunday nights, train operation is paused for track maintenance work. Therefore, the trains departing after Wednesday need much more time (up to 142 hours). Because the stoppage time on the way is long, the average train speed from origin to destination is less than 21 km/h, which is almost the same as the current transportation speed between Hanoi and Ho Chi Minh by conventional line. The driving time interval is assumed to be 10 minutes, which means 12 trains per day/ per direction.

Assumptions
- Distance between yard: 400km
- Scheduled speed: 100km/h
- Service time: 0:00-6:00
- Train interval: 10 minute

Capacity and Resource (Two direction)
- Number of train: 12 train/day/direction
- Driving time: 76-142 hour
- Effective (Average) speed: 21-11 km/h
- 12 train set X 4 days X 2 direction + reservation =110 set
- 12 storage track X 3 intermediate yard X 2 direction = 72 track
- 2 freight terminal (Hanoi and HCMC)

Freight Service on HSR line (400 km of yard distance)



Remark: Number of trains operated in a single day is 96 trains (12 train/ direction*2 direction*4 section)
Source: JICA Study Team

Figure 1.16: Weekly Train Diagram

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4 https://www.excite.co.jp/news/article/Trafficnews_79034/ (Referenced 2019-07-01)
5 https://www.khi.co.jp/mobility/rail/locomotive.html (Referenced 2019-07-08)
6 The distance between Hanoi and Ho Chi Minh was set as 1,600 km to simplify the analysis.

(5) Required Investment

The expected amount of investment necessary for freight train operation is shown in the table below.

Table 1.21: Required Investment for Freight Transportation

Unit of Costs: Million USD

		Unit Cost	Volume	Cost	Total Cost	Note
Vehicle	Locomotive	[redacted]				
	Shunting Locomotive					
	Container car					
Equipment	Freight Station				Removed	
	Storage Yard					
	Inspection Facility					
Subtotal						
	Others					
Total						

Source: JICA Study Team

The unit price of the freight station is lower than that of the storage yard because the number of indwelling lines of the freight station is 12, whereas the detention facility requires 24 trains for both directions.

The transportation capacity for this facility is as follows.

- Maximum transport volume per train: 1,046 tons
  (Two 20 ft containers on 1 freight car, maximum load weight in a container: 21.8 tons)
- Annual transportation volume for both directions: 6.5 million tons
  (1,046 tons / train * 12 train / day * 365 days * 5/7 * 2 because weekly operation is 5 days)

If loading efficiency is assumed to be 70%, the annual transportation volume is 4.55 million tons for both directions, and the transport ton-kilometer is 7,280 million ton-kilometers. Comparing this with the actual transportation of VNR in 2011 (in the below table), the transport capacity of high speed railway cargo is 63% in transport tonnage and 178% in transport ton-kilometers.

Table 1.22: Transportation Volume of VNR

Unit: 1000 VND

	Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Freight	Transport Volume(ton)	8,281,847	8,771,002	8,687,964	9,153,244	9,019,398	8,387,424	8,159,066	7,774,757	7,197,585
	Transport Volume(ton-Km)	2,674,911,291	2,681,033,130	2,927,527,906	3,446,608,971	3,900,202,927	4,106,128,895	3,807,095,231	3,900,668,605	4,100,545,983
	Average transport distance(Km)	323	306	337	377	432	490	467	502	570
	Revenue	606,033,612	649,609,143	657,852,575	796,597,000	999,393,000	1,189,426,000	1,073,837,000	1,163,146,000	1,566,217,738
Passenger	Transport Volume(passenger)	11,586,383	12,941,137	12,768,570	11,572,796	11,571,232	11,333,806	11,072,375	11,047,729	11,981,849
	Transport Volume(passenger—Km)	4,041,713,827	4,376,385,203	4,557,622,255	4,333,651,433	4,659,483,872	4,492,260,997	4,138,054,317	4,377,860,733	4,571,080,043
	Average transport distance(Km)	349	338	357	374	403	396	374	396	382
	Revenue	1,045,758,007	1,169,779,612	1,274,293,659	1,350,693,000	1,543,225,000	1,726,433,000	1,692,411,000	1,860,482,000	2,360,291,957
Parcel	Transport Volume(ton)	103,155	107,479	98,662	91,062	95,657	92,291	88,397	86,766	87,467
	Transport Volume(ton-Km)	50,517,100	55,166,486	51,764,407	52,498,154	58,733,969	59,153,825	57,443,725	60,196,670	62,024,786
	Revenue	28,372,906	31,942,971	31,993,204	35,315,000	41,268,000	49,443,000	50,077,000	50,165,000	61,235,898
Total	Total revenue	1,680,164,525	1,851,331,726	1,964,139,438	2,182,605,000	2,583,886,000	2,965,302,000	2,816,325,000	3,073,793,000	3,992,394,842

Source: VNR

(6) O&M Cost for Freight Operation

The O&M costs are assumed as follows.

Table 1.23: O&M Cost for Freight Operation

Cost	Amount (million USD)	Note
Personnel	[redacted]	[redacted]
Material	[redacted]	[redacted]
Power	[redacted]	Removed
Maintenance	[redacted]	[redacted]
Total	[redacted]	[redacted]

Source: JICA Study Team

1.4.4 Summary

When high speed passenger trains and freight trains are operated at the same time, the operable number of trains is significantly reduced due to the differences in speed. Also, there is a possibility that cargo loaded on freight cars can fall, due to train draft from high speed trains, posing serious accident concerns. 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.

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 lines during the day. As a result, the speed of the freight trains would decrease, decreasing the operation efficiency (even if many vehicles are used), and investment profitability would deteriorate.

There are levels of A1, A2, B1, and B2 proposed in JICA's Previous Study as improvement plans for the north-south railway corridor. Level A2 is an improvement plan to maximize the capacity of the existing single-track line up to a line capacity of 50 trains/day for both directions, connecting Hanoi and Ho Chi Minh in 25.4 hours.

With freight transportation on the high speed railway line, a travel time between Hanoi and Ho Chi Minh of more than 76 hours, and operable freight train per day per both directions at 24. This freight transportation is obviously less efficient than level A2.

When railway capacity needs to be increased, it is preferable to operate the same type of vehicles at the same speed. This is the same for both high speed railway and conventional lines. If the speed of freight trains were increased to that of passenger trains, or the express trains are moved to the high speed line, more trains could operate on the line. The mission of the high speed railway is the high speed, and its function should not be disturbed by the operation of slower freight trains.

1.5 Scenario for HSR Development

Although there is no standard definition for HSR, it can be considered as a railway with a speed of 200 km/h or more. For track standard, a gauge of more than 1,435 mm for running stability, and minimum curve radius of more than 2,000 m corresponding to centrifugal force should be considered.

However, since the construction costs of HSR are expensive, phased improvements of the existing railway are proposed. This section summarizes the Previous Study on the feasibility of these proposals and presents recommendations.

1.5.1 Improvement of Existing Railway

(1) Track Gauge Conversion

Case studies of gauge conversion from meter gauge to standard gauge exists. In case of Japan's Akita Shinkansen of 127 km, it took five years for construction work stopping the train operation continuously. Because the construction period is long, the gauge conversion can be applied only to sections where an alternative route can be secured during the construction period.

(2) Dual Gauge Track

The dual gauge track is another alternative. It can run high speed passenger trains on the standard track and freight trains on the meter track. It can shorten the period of stopping train operations by shortening the construction sections.

However, mixed operations between passenger and freight trains reduces the line capacity due to the speed difference, meaning the speed of passenger trains will be limited. The above-mentioned Akita Shinkansen has a section with dual gauge tracks, providing a maximum speed of 130 km/h and a scheduled speed of 85 km/h. There is no example of a dual gauge track being utilized for a train speed of more than 200 km/h.

One challenge of the dual gauge is the switching device. It restricts the speed even on the straight stretches, and is complicated, with various type of structures that make it difficult to maintain.

Furthermore, since the track center differs between the meter and the standard tracks, attention must be paid to separating the track and the platform. In some cases, it is necessary to rebuild bridges and tunnels.

1.5.2 Phased Development of High Speed Railway

From the viewpoint of finance and construction ability, it is reasonable to construct in phases for a long railway line. In this survey, the construction phases are assumed for two cases, Two-step Case and Five-step Case; and is examined by setting the phases to 3 sections of 2 phases and 5 sections of 5 phases, respectively. This idea of phased development is described in Chapter 2.1.1 construction process.

For the short and low demand sections, it is possible to construct a single-track line and upgrade it to a double-track later. The construction cost of the single-track railway is 70% of the double track, so the initial investment amount can be reduced. However, in the track doubling stage, it will cost 70% more of the double track again. Therefore, the total construction costs will increase by 40%.

1.5.3 Speed Improvement

This is an idea to build the new railway for 160-200 km/h and improve the train speed in the future. It can reduce the initial investment amount as it makes the route selection easy, allowing a small curve radius. However, it is difficult to upgrade the completed structure in the later phases. Curve improvement requires land acquisition and construction of a large-scale short-cut route, which requires a lot of investment.

1.5.4 Summary

As mentioned above, it is not realistic to convert the meter gauge track once constructed or to improve the route alignment.

In the next section, the adequacy of operating at a low speed on the route constructed for high speed is examined.

1.6 Influence on the Investment and Operation Cost caused by Train Speed

1.6.1 Investment Cost

In this section, two options are compared. One is a plan to operate the railway at 320 km/h from the opening. Another is to start operation at 200 km/h and later improve the speed up to 320 km/h.

If the operation of 320 km/h is assumed in the future, it is necessary to construct in consideration of the durable years and replacement cost of equipment. Generally, the durable years is 50 to 60 years for civil engineering structures, 20 to 40 years for electric power equipment, 30 years for signaling equipment, and 15 to 20 years for high speed rail vehicles.

During the renovation of railway facilities, it is essential not to interfere with the train operations. For this reason, while using old facilities, new facilities are brought in and switched over little by little. As a result, a long period is required for renewal, and its cost is comparable to the cost of new construction. Only the replacement of rolling stock is relatively easy.

(1) The Investment Cost for Rolling Stock

The number of required train sets that transports passengers depends on its speed. High speed trains can make more round trips than low-speed trains.

1) The difference between the cycle time and possible round trips per day

If the speed is high, the cycle time between the departure and arrival stations is short. As a result, the number of round trips per day increases. The table below shows the comparison of one day round trips in 2030 between 320 km/h and 200 km/h speeds.

Table 1.24: Cycle Time and Number of Roundtrips per Day

Section		320 km/h	200 km/h
North (Ngoc hoi – Vinh)	**Running time (one way)**	79 min.	100 min.
	Turn back time	40 min.	40 min.
	Cycle time	238 min. (3:58)	280 min. (4:40)
	Number of round trips in 16 hours	4	3
South (Nha Trang – Thu Thiem)	**Running time (one way)**	94 min.	125 min.
	Turn back time	40 min.	40 min.
	Cycle time	134 min. (2:14)	165 min. (2:45)
	Number of round trips in 16 hours	7	5

Source: JICA Study Team

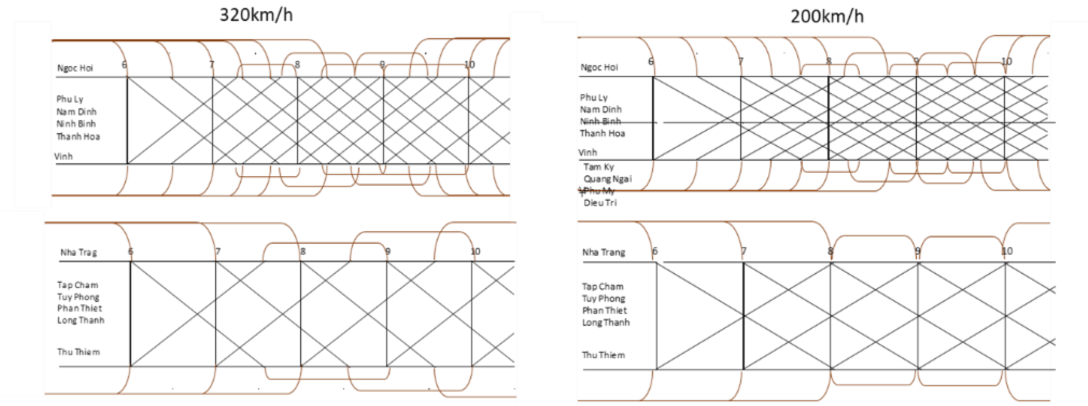
In other words, the high speed train operation can reduce the number of train sets in transporting a certain number of passengers compared to low-speed operation.[7]

2) The difference in train sets

The below train diagram for early morning indicates the required train sets which were on the storage tracks at night. For example, trains of 320 km/h on storage lines at Ngoc Hoi depart at

[7] In order to reduce the number of train set, shortening the cleaning time at the terminal station is also effective. Here, we assumed the turn back time of 40 minutes reflecting the actual situation in Vietnam. Japan's turn back time is 15 minutes.

6:00 am, 6:30 am, 7:00 am, 7:20 am, 7:40 am and 8:20 am. The other trains such as 8:00 am, 8:40 am, and 9:00 am turn back from arrival lines at Ngoc Hoi.



Source: JICA Study Team

Figure 1.17: Train Diagram for the Morning

The following table shows the comparison of required train sets between 320 km/h and 200 km/h in 2030 in the north and south sections.

Table 1.25: Required Train Sets

Section	320 km/h	200 km/h	Difference
North (Ngoc hoi – Vinh)	12	14	2
South (Nha Trang – Thu Thiem)	6	6	0
Sub-total	18	20	2
Reserved train sets	4	4	0
Total number of the train set	22	24	2

Remark: At least two reserved train sets are necessary for each section.
The table indicates that the 320 km/h operation can save a total of two train sets, compared to the 200 km/h operation.
Source: JICA Study Team

3) The procurement cost of train sets

The price of the rolling stock varies depending on the quantity ordered and the speed. Here, based on the vehicle price[8] of the 320 km/h speed train, JST assumes the price of motor and trailer vehicle, and M/T ratio necessary for 200 km/h as shown in the next table.

The table indicates that the 320 km/h rolling stock system would be cheaper by 4% than the 200 km/h system.

Table 1.26: The Price of Rolling Stock

Item	320 km/h (8M2T)	200 km/h (6M4T)	Note
[redacted]	[redacted]	[redacted]	8 cars for 320 km/h, 6 cars for 200 km/h
[redacted]	[redacted]	[redacted]	2 cars for 320 km/h, 4 cars for 200 km/h
Removed	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	

Source: JICA Study Team

8 "Perfect guide of active Shinkansen" KASAKURA publishing company

(2) Possibility to Change the Track Structure

1) Track structure on Curves

On viaduct and tunnels, the slab track is planned to be adopted considering to minimize future maintenance. On the other hand, in principle, the ballasted truck is applied on the cut and embankment sections considering possible consolidation settlement. The total curve section length is around 150 km, and ballast and slab section lengths are almost equal.

Table 1.27: Truck Structure and Curve Lengths (meter)

North Section		Total	Ballast	Slab
Ngoc Hoi	Phu Ly	15,811	2,846	12,965
Phu Ly	Nam Dinh	15,736	0	15,736
Nam Dinh	Ninh Binh	13,719	0	13,719
Ninh Binh	Thanh Hoa	9,357	6,874	2,483
Thanh Hoa	Vinh	32,848	27,844	5,005
Total		87,472	37,564	49,908
South Section		**Total**	**Ballast**	**Slab**
Nha Trang	Thap Cham	8,274	4,138	4,136
Thap Cham	Tuy Phong	21,189	11,058	10,131
Tuy Phong	Phan Thiet	6,240	2,488	3,753
Phan Thiet	Long Thanh	17,469	11,902	5,567
Long Thanh	Thu Thiem	15,647	2,596	13,051
Total		68,818	32,181	36,637

Source: JICA Study Team

2) The difference of track between 320 km/h and 200 km/h

Since the *cant* is proportional to the square of the speed, the cant of 320 km/h is 2.56 times 200 km/h, as shown in the table to the right.

For the setting of cant, the inner rail is lowered by half of the cant, and the outer rail is raised by half, so that the height of the gravity center does not change between the entrance and exit of the curve, and would avoid unnecessary up and down movements.

Table 1.28: Comparison of Cant

R (m)	Equilibrium Cant (mm)		Note
	320 km/h	200 km/h	
5,000	242	94	C =11.8×V×V/R
6,000	201	79	
8,000	151	59	
10,000	121	47	

Source: JICA Study Team

The cant set for 200 km/h must be corrected before the train accelerates to 320 km/h. Actually, it is impossible to correct the cant of the entire line at once. Therefore, the train speed shall be planned according to the progress of cant correction. Otherwise, the ride comfort would become extremely poor and the risk of derailment would increase.

3) The cant correction for ballast track

For the ballast track, cant correction is possible. The conceptual correction method is as follows.

(i) Preparation in advance
- Make the ballast of the curve sections thick in advance, even for the operation at 200 km/h

(ii) Correction of cant
- Close both railway tracks at night, and stop all train operations.

- Scrape ballast from inner rail side and move to outer rail side of the track.
- Make continuous tamping work by tamping machine based on absolute benchmark height.
- The work speed depends on the cant correction value; however, in general, it is 4-500 m per night.
- The value of cant correction at one time is less than 50 mm for the stability of the track.
- For high cant correction, multiple correction works are required.
- One curve must be finished in one night.
- Check the track condition carefully after the work.
- The speed of the first train on the track should be around 100 km/h, then gradually speed up.
- Make spot surfacing at night, if necessary.

(iii) Work

- The work items, workable track length per one night, cost per one night, the required number of work repetitions from 200 km/h to 320 km/h, etc., are shown in the following table.

Table 1.29: Cost Estimation of Cant Correction from 200 km/h to 320 km/h

Work Item	Cant correction	Spot surfacing	Total
Workable track length/night (m)	500	500	
Cost/ night (Thousand USD)	5	10	
Number of work repetitions (Time)	3	1	
Cost for 500 m of track length (Thousand USD)	15	10	25
Cost for 1 km of track length (Thousand USD)			50
Cost for 1 km of line length (Thousand USD)			100

Source: JICA Study Team

As the line length of the ballasted curve is 69,745 km (north section: 37,564 km, south section: 32,181 km), the total cost would be around 6.97 million USD. It takes 4 nights of work for 500 m track length as shown in the table. In other words, 8 nights are necessary for 1 km of line length or 125 m/night. Therefore, 558 work nights are required if all the work is done by one party.

4) The cant correction for slab track

For the slab track, the cant correction is almost impossible. In the cant correction work, the inner rail side of the panel is lowered, and the outer rail side is raised. Working experiences in Japan were done only for short sections of 50 m or less, and 4 hours of work was needed over 5 nights. It is impossible to undertake this where the total track length is 180 km.

As a possible cant modification method, the following plans could be considered.

A. Initially construct a ballast track corresponding to 200 km/h and upgrade it for a slab track when going up to 320 km/h.
B. Develop a rail fastening devices capable of changing the rail height, install them initially, and raise the outer rail when the speed is improved.
C. Set the cant setting value to an intermediate value between 200 km/h and 320 km/h and ignore the deterioration of ride comfort or decrease the train operation speed if necessary.

Every plan has its advantages and disadvantages. Plan A requires a long work period near the operating line. Plan B seems attractive; however, the possibility of development is unknown, and even if it can be developed, it may be expensive. Plan C can cause problems in the future.

Here, the proposed procedure and expenses for Plan A is considered, but this also cannot fully guarantee the feasibility:

(i) Construct ballast track for 200 km/h

(ii) Remove ballast track work
Close one railway track, and limit the speed of another track for safety
Remove the ballast track completely
The removal speed is estimated to be 500 m/day

(iii) Construct new slab track for 320 km/h
Construct the new slab track
The speed of construction is around 200 m/day

(iv) The overall duration and cost of installing a new slab track
200 m/day since the slower work controls the overall work
The longest slab section length in the curve is 15.7 km between Phu Ly and Nam Dinh, and the work takes nearly 157 days (=15.7*2/0.2) for double tracks.
In total, 160 days of track closure is necessary for the section between Phu Ly and Nam Dinh.

(v) The additional cost for the construction and removal of ballast track
The cost for the construction of slab track is included in the initial cost.
The additional cost is the construction and removal of ballast track.
1.1 million USD/track-km for the construction and 0.3 million USD/track-km for the removal are assumed, which is 2.8 million USD/line-km.

5) The overall cost of the cant correction

The cost for the cant correction of ballast track was assumed as 0.1 million USD/km, and 2.8 million USD/km for the slab track section, which consists of the construction and removal of ballast track based on Japanese experience. The table below shows the summary of these estimations. The table indicates that the cost of cant correction is 242.2 million USD. Additionally, a long, dangerous period for the cant correction needs to be taken care of, and it would disturb the train operations.

Table 1.30: Cost for Cant Correction

	Curve Line length (km)		Unit Cost (mil. USD/km)		Cost (mil. USD)	
Track	**Ballast**	**Slab**	**Ballast**	**Slab**	**Ballast**	**Slab**
North Section	37.5	49.9	0.1	2.8	3.75	139.7
South Section	32.2	36.6			3.22	102.5
Total					6.97	242.2

Source: JICA Study Team

(3) Summary of Construction Cost

As mentioned at the beginning, only the vehicle cost will affect the initial investment cost because of the long lifetime and expensive replacement cost of civil structures and electric facilities. From the initial investment amount, the 320 km/h operation from the beginning is preferable. The reason for this is as follows.

(i) 200 km/h operation requires more train sets to run the same number of trains, which increases the rolling stock cost.
(ii) Cant improvement is unnecessary.

1.6.2 Operation Cost

The operation and maintenance cost would be less with a slower speed. The amount is as follows.

(1) Power Cost

1) The electricity fee in Vietnam

According to the Japan External Trade Organization (JETRO) report in 2017, the average industrial electricity fee in Vietnam is 0.077 USD/kwh.

2) Difference in power consumption

When the maximum speed is lowered from 320 km/h to 200 km/h, the power consumption decreases. Regarding the speed and running resistance of the Shinkansen, the following empirical formulas[9] are expressed.

R = 1.60 + 0.0350 V + (0.0197 + 0.00241*n) *V^2/W

Where

R: Running Resistance (kgf/ton)
V: Train Speed (km/h)
W: Weight of Rolling stock (tonf) 453.5 tonf for E5 series
L: Train length (m) 250 m

The calculation result is shown in the following table.

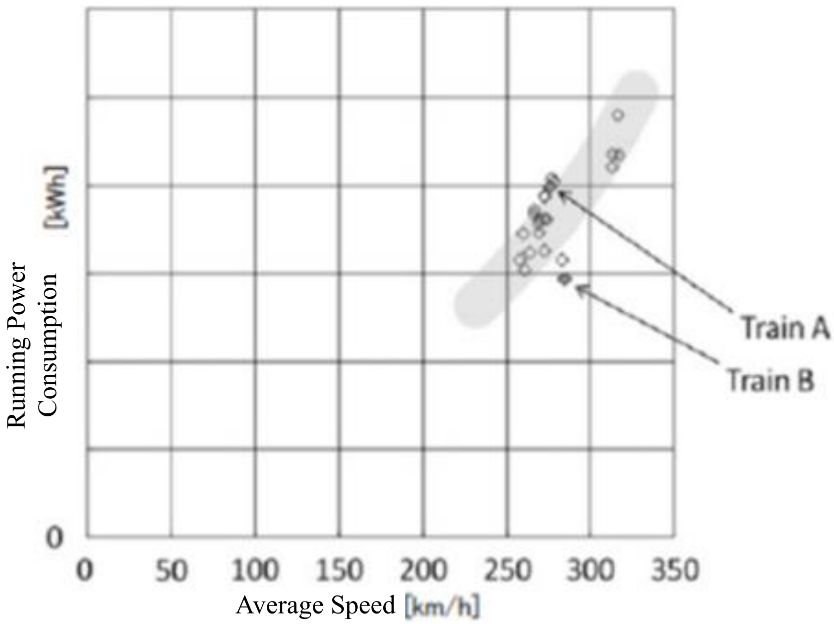
Table 1.31: Speed and Running resistance of Shinkansen

Max. speed	320 km/h	200 km/h	Ratio
Running Resistance	22.7 kgf/ton	12.5 kgf/ton	0.55

Source: JICA Study Team based on the above-mentioned equation

The power consumption of the E5 train in various modes is shown in the following figure from JR East.

[9] "Handbook for the estimation of the hauling capacity" JNR (1984)



Source: Mizuguchi, Y. and Sonoda, H. (2015). Measurement and Analysis of Driving Energy in the Shinkansen, *Technical Review-No. 51*, *JR EAST,* 21-26

Figure 1.18: Speed and Energy Consumption

Based on this information, the power consumption for the 200 km/h train is assumed at 55% of the 320 km/h train.

3) The difference in power cost

The next table shows the power consumption and cost of a railway operated at 320 km/h and the estimated cost of a railway operated at 200 km/h in 2030.

Table 1.32: Comparison of Power Consumption Cost (2030)

Speed	Max. Speed	Section		
320 km/h	Section	North	South	Total
	Section length (km)			
	Number of trains (both directions)			
	Train-km / day (thousand)			
	Train-km / year (thousand)		Removed	
	Power consumption (million kwh)			
	Power cost /year (million USD)			
200 km/h	Total (million USD)			

Source: JICA Study Team

(2) Track Maintenance Cost

1) Track destruction

When the train speed decreases, track destruction slows down. Here, it is assumed that the track destruction is proportional to the speed. Therefore, the costs for the track, structure maintenance, and maintenance machinery are reduced.

2) Track maintenance cost

When the train speed decreases from 320 km/h to 200 km/h, the track maintenance cost is assumed to decrease approximately by 38%.

(3) Crew Cost

1) Number of crew

If the train kilometers are the same and the train speed is slow, the working hours of crew will be longer. As shown in Table 1.25, the cycle time of the north section is 238 minutes at 320 km/h and 280 minutes at 200 km/h, and the ratio is 1.17. The south section is 134 minutes at 320 km/h and at 165 minutes at 200 km/h, and the ratio is 1.23. From the above, it is assumed that the number of crew members is assumed to increase by 20% in the case of railway operation at 200 km/h compared to 320 km/h.

2) Crew cost

The 320 km/h system's crew cost is cheaper by 20% than the 200 km/h system.

(4) Summary of O&M Cost at Different Speeds

The operation costs at different operational speeds are summarized in the next table. The slower the speed, the lower the operating costs. The reasons are as follows:

(i) Energy consumption is lower due to speed reduction.
(ii) Track maintenance cost is lower because track destruction decreases.
(iii) Expenditure on crew is slightly lower.

Table 1.33: Comparison of O&M Cost

Expenditure		320 km/h	200 km/h	Difference
Operation cost (Million USD/year)	Power		Removed	
	Track Maintenance			
	Crew			
	Total			

Source: JICA Study Team

On the other hand, consideration of the following matters is required.

(i) The function of the facility is not sufficiently demonstrated.
(ii) Passengers' benefits (time savings) due to high speed transportation cannot be obtained sufficiently.
(iii) Socio-economic effects (enterprise location and land use form) by high speed rail are limited.
(iv) As a result, demand decreases.

The cant setting for trains with different speeds

A. General

It is possible for the 120 km/h train to operate on the track calibrated for 350 km/h.
Since the cant is set assuming the case that the 350 km/h train stops (0 km/h) on the track if necessary.
However, if the cant corresponds to 350 km/h, the gravity force acts on the 120 km/h train (cargo in the freight car is pushed), which is not preferable. On the other hand, if the cant corresponds to 120 km/h, the excessive centrifugal force acts on the 350 km/h train, which is also undesirable.

Below describes the method of harmonization of the above issues:

1) Set the cant Cm on which 120 km/h train runs at the limit of cant excess.
2) Estimate the train speed operating on the settled cant Cm with the limit value of cant deficiency.
3) Consider the estimated train speed to be the maximum speed on curves.

The limit value of the cant excess and the cant deficiency varies depending on the rolling stock, but both are generally considered to be 60 mm.

B. Calculation example:

At first, consider the equivalent cant of the 120 km/h train.
When R = 4,000 m, the equivalent cant Ce is 42 mm.

Ce = 11.8*120*120/4,000 = 42

As the allowable cant excess is 60 mm, setting cant Cm can be 102 mm.

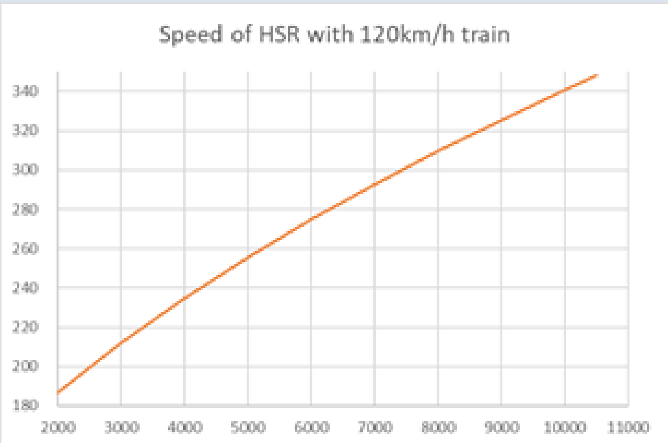
Cm = Ce + 60 = 42 + 60 = 102

The freight train can run at the speed of 120 km/h
As the allowable cant deficiency is 60 mm, the passenger train can run at the speed of 234 km/h.

V = sqrt ((Cs + 60) *4,000/11.8) = sqrt ((102 + 60) *4,000/11.8) = 234

C. Speed and curve radius

The relation between the speed of HSR train and curve radius is shown below:



Source: JICA Study Team

1.7 Night Train Operation

1.7.1 Overview

(1) The Operation of Night Trains

The concept of night train operation is to operate non-stop from after 22:00 pm to before 08:00 am and allow passengers to sleep for 8 hours or more, even if there are many exceptions.

Night trains have the following features.

1) Usually, night trains operate at a slower speed than the day trains, either to provide sufficient time to sleep, to allow for splitting and joining to serve multiple destinations, or to operate around freight trains or network congestions.
2) Access to stations in the city center is difficult, particularly in the morning. In Japan, night trains have been withdrawn due to the insufficient track capacity in the morning commute time near the terminal station.
3) Longer journey times and trains means less productive rolling stock and staff. The staff is required to work overnight and away from home; and additional services such as shunting, bed-making, and laundry are needed.
4) Night trains usually include several types of accommodation such as regular seats, reclining seats, couchettes, and sleeping compartments. The rolling stock of night trains is more complex, built in smaller volumes and carries fewer passengers per vehicle.
5) The Reduced Mobility (PRM) is typical for passengers. As on long-haul aircraft, better accommodation requires more space per passenger.

1.7.2 Japanese Experience on Conventional Lines

Japan had a broad network of night trains, enabling travelers to arrive in other cities by early morning, and this was considered to boost the economic development of the regions they connected. However, services have declined recently, for the following reasons.

1) Shinkansen
   The development of the Shinkansen network has reduced the period of journey and offers both faster journeys and lower fares than night trains.
2) LCC
   The competition with air travel, especially low-cost carriers, has eroded the night train market.
3) Hotel
   Affordable hotels have become more common. Hotel chains are established across the entire country and have reduced the need for overnight travel.

It may be reasonable to consider that night trains continue to decline. But here, the study of JNR is traced for the night train on Shinkansen.

1.7.3 Sanyo Shinkansen Technology Investigation Committee

(1) Purpose of the Committee and Items to be Discussed

After the opening of the Tokaido Shinkansen of 515 km in 1964, it was decided to stretch it westward. In this construction, it was considered that there was no major revision of the standards applied to the Tokaido Shinkansen. However, from the viewpoint of reflecting previous experience and technology, the Sanyo Shinkansen Technical Standards Investigation Committee was established, whereby a survey that took less than a year from 1965 was conducted.

The main subjects to be investigated were the maximum speed, night train operation, two-way operation facility, and additionally, the number of trains and the track standard. The maximum speed was assumed to be the same as the Tokaido Shinkansen for the time being. However, places that would be difficult to modify features such as curve radius, gradient, etc., were considered so as not to hinder speed improvements in the future.

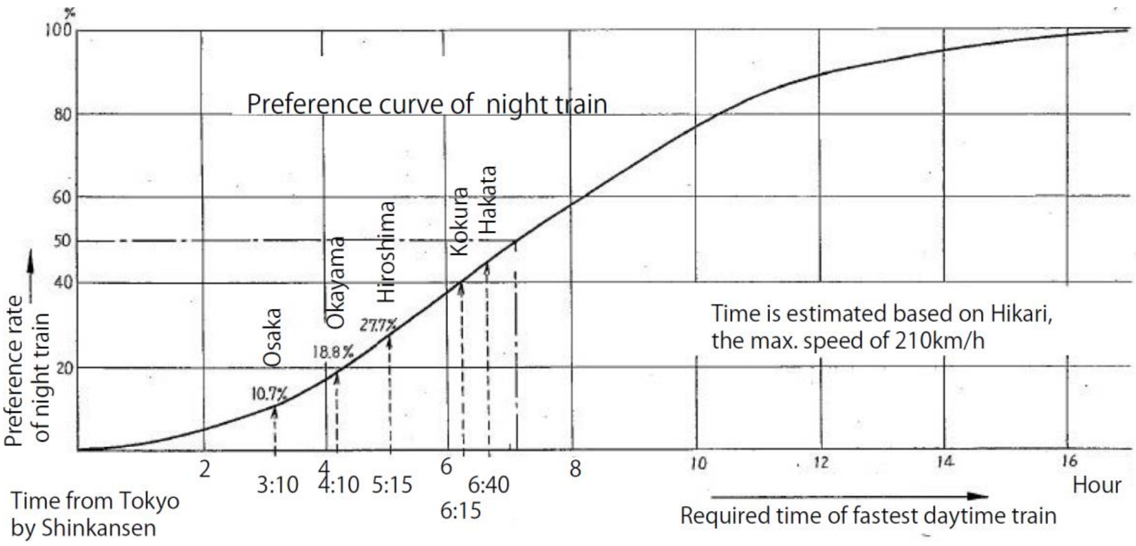
Regarding the night train, it was considered to be necessary when the Shinkansen was extended to Hakata, 1,069 km from Tokyo. However, in the case of the opening to Okayama, 676 km from Tokyo, no night train was deemed necessary. From the viewpoint of night train operation and the time period for track maintenance, the two-way operation facility is indispensable. Details of the facility and the location to be installed were decided to be studied separately as part of the construction plan.

1.7.4 Night Train Operation

The focuses on night train feasibility were demand for night train travel, railway maintenance system, and interactive operation facility. The outline of each is as follows.

(1) The Demand for Night Train Customers

Next figures shows the influence of the time required to the destination on the choice between the daytime train and night train based on the actual trend of Japanese passengers in 1954-1962. It indicates that preference of the night train increases if the time required to the destination exceeds 7 hours, the night train is preferred over the daytime train.



Source: Report on Sanyo Shinkansen Technology Investigation Committee (JNR, 1966)

Figure 1.19: Preference Curve of Night Train

(2) Maintenance Issues Related to Night Train Operation

1) The necessity of the two-way operation

Based on the experience with the Tokaido Shinkansen, the period of actual time for track maintenance was considered to be 4 hours a day for continuous tamping and 8 hours for the replacement of track panel.

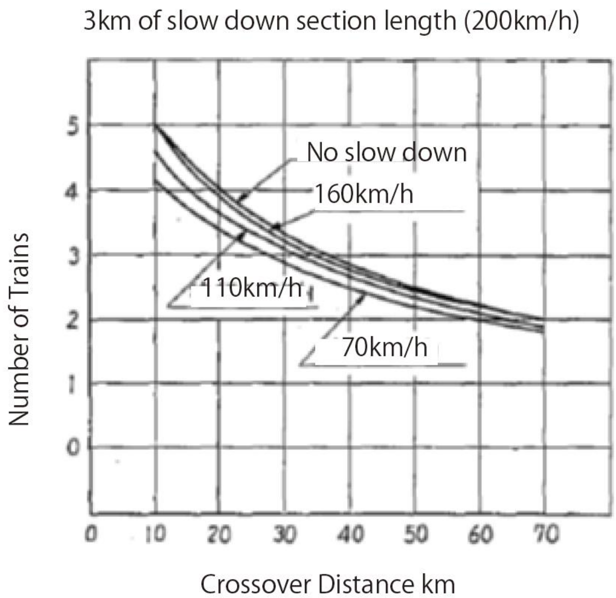
When the night train is operated, it is necessary to carry out two-way operation; trains run bi-directionally on one track, and maintenance work is done on another track.

2) Crossover distance and number of trains when performing the two-way operation

The distance between the crossover section and speed near the maintenance site area are the key factors to control the number of operable trains. Those are assumed as follows:

(1) The distance between the crossover is about 20 km. In this case, the number of trains will be 3-4 trains/one-way/hour and will not interfere with either maintenance of civil engineering or electrical work.
(2) The train speed in the maintenance section shall be 110 km/h or less based on the experience of the conventional line.
(3) The construction cost of crossover is 50 million JPY/place excluding electrical work.

The next figure shows the relation between the crossover distance and the number of operable trains per hour. It indicates that the crossover distance is 20 km and the speed is 70 km/h; therefore, 3 trains per hour can be operated.



Source: Report on Sanyo Shinkansen Technology Investigation Committee (JNR, 1966)

Figure 1.20: Cross over Distance and Number of Trains

(3) Single Track Operation

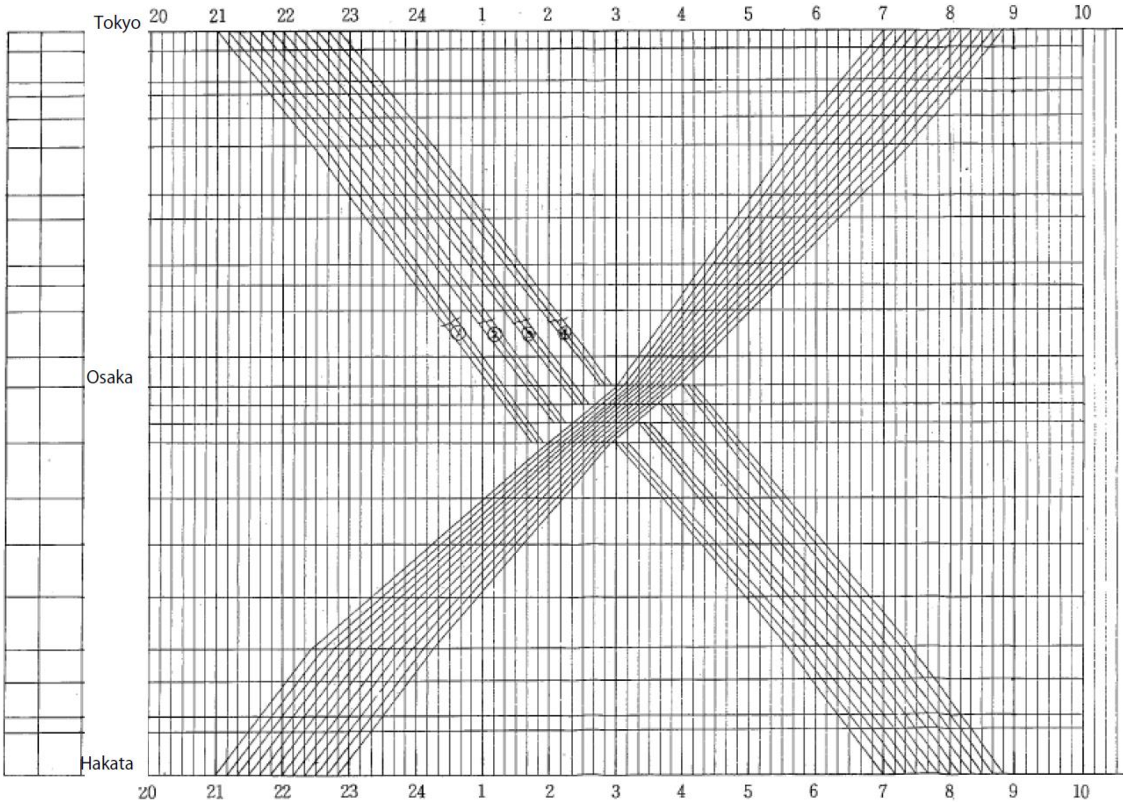
Below assumptions are set to consider a train diagram on a single-track:

1) The conditions set for the train diagram

(1) Number of trains: 12 trains
(2) The time required: Tokyo-Hakata 10 Hour
(3) Available time for train operation (Tokyo, Hakata):
Departure time 21:00-23:00, Arrival time 7:00-9:00
(4) Two-way operation facility:
Four interchange points are installed where trains in both directions are crossing. The two-way operation facility is introduced not only in the cross-over sections, but also in the entire line in order to increase the number of trains in the future, and to better organize operations at the time of the accidents.

2) Diagram

The diagram assumed is shown below.



Source: Report on Sanyo Shinkansen Technology Investigation Committee (JNR, 1966)

Figure 1.21: Conceptual Train Diagram

1.7.5 Study on Night Train in Vietnam

(1) The Possibility of a Night Train

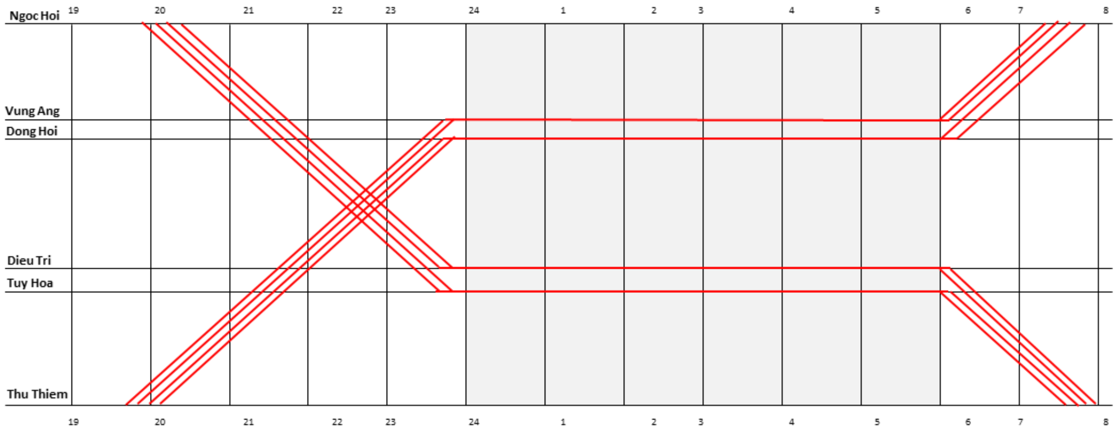
The time required between Hanoi and Ho Chi Minh is 5 hours 20 minutes by high speed train. In this case, if the night train preference rate explained above can be applied, it shall correspond to 30% of the total passenger demand, and there is a high possibility that a night train will be accepted. This is a strong reason to operate night trains.

(2) Assumed Train Diagram

The arrival time of the night train depends on people's behavior patterns. The favorable time for departure is 20:00 pm - 21:00 pm in the evening, and 7:00 am - 8:00 am the next morning for arrivals. It takes 6 hours for track maintenance, and there are two operation alternatives during the maintenance hour; one is to stop all trains completely, and another is to run trains slowly on a single track by the two-way operation method.

<Stop all trains>
It is highly safe and can reduce nighttime driving staff. Moreover, there is no influence on the surrounding environment such as noise vibration.

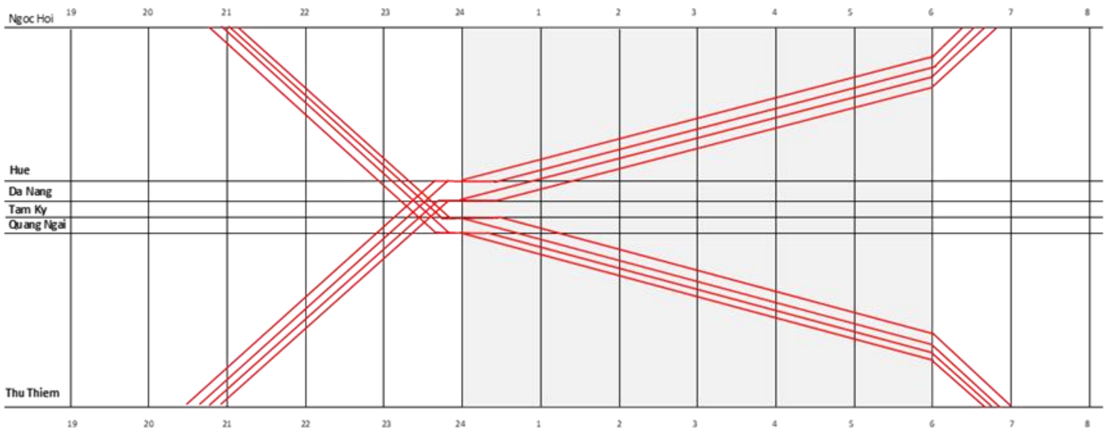
The down trains stop at Dieu Tri and Tuy Hoa, and the up trains stop at Vung Ang and Dong Hoi at night. The number of night trains are controlled by the number of arrival/departure lines.



Source: JICA Study Team

Figure 1.22: Train Diagram (Stop All Trains)

<Slowing down>
Bi-directional trains are passing each other between Hue – Quang Ngai. As the trains run slowly during the maintenance period, the required time to reach the station is shorter and arrives at the destination early in the morning. The number of trains is not affected by the number of departure/ arrival lines at the station. Two-way operation equipment is indispensable.



Source: JICA Study Team

Figure 1.23: Train Diagram (Slowing Down)

(3) Rolling Stock

Explanations of the night train vehicles are in Chapter 4.4.1.

(4) Future Initiatives

A considerable night train demand may generate in the HSR in Vietnam. Therefore, the data collection from other countries and UIC on night train is important

For the night train, facilities for two-way operation on a single track is indispensable. The facility is useful not only for night trains but also for track maintenance and train operation when the train schedule is disturbed.

2. Necessity of Investment

2.1 How to Proceed

2.1.1 Construction Process

(1) Concept of Construction Process

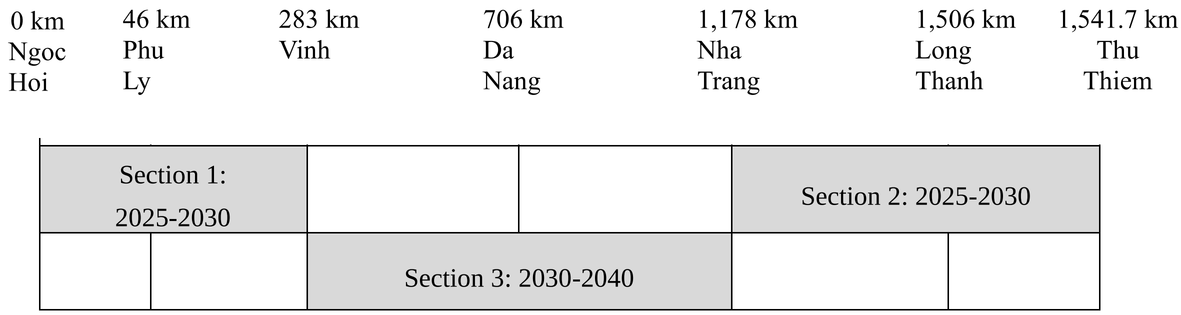
This project is a large project covering a total length of 1,541 km. Since the construction requires a considerable amount of money and effort, it is reasonable to divide the sections into several sections and construct each section step by step. The principles of the sectioning are as follows.

1. Prioritize the section with high demand.
2. From the characteristics of HSR transport, section length shall be around 300 km or more.

In this survey, the JICA Study Team considered two cases; Two (2) -step Case - opening of the entire line by 2040, and Five (5) -step Case - by 2070.

(2) Two-step Case

Two-step Case plans to divide the whole line into three sections, initially opening Ngoc Hoi – Vinh (282 km) in the north section and Nha Trang – Thu Thiem (364 km) in the south section by 2030, and Vinh – Nha Trang (896 km) by 2040. The construction process and outline are shown in the following figure and table.



Source: JICA Study Team

Figure 2.1: Construction Period of Two-step Case

Table 2.1: Outline of Two-step Case

Section	End Points	Distance	Construction Year	Opening	Max. Operation Speed
Section 1: North Section	Ngoc Hoi – Vinh	283 km	2025-2030	2030	320 km/h
Section 2: South Section	Nha Trang – Thu Thiem	363 km	2025-2030	2030	320 km/h
Section 3: Middle Section	Vinh – Nha Trang	896 km	2030-2040	2040	320 km/h

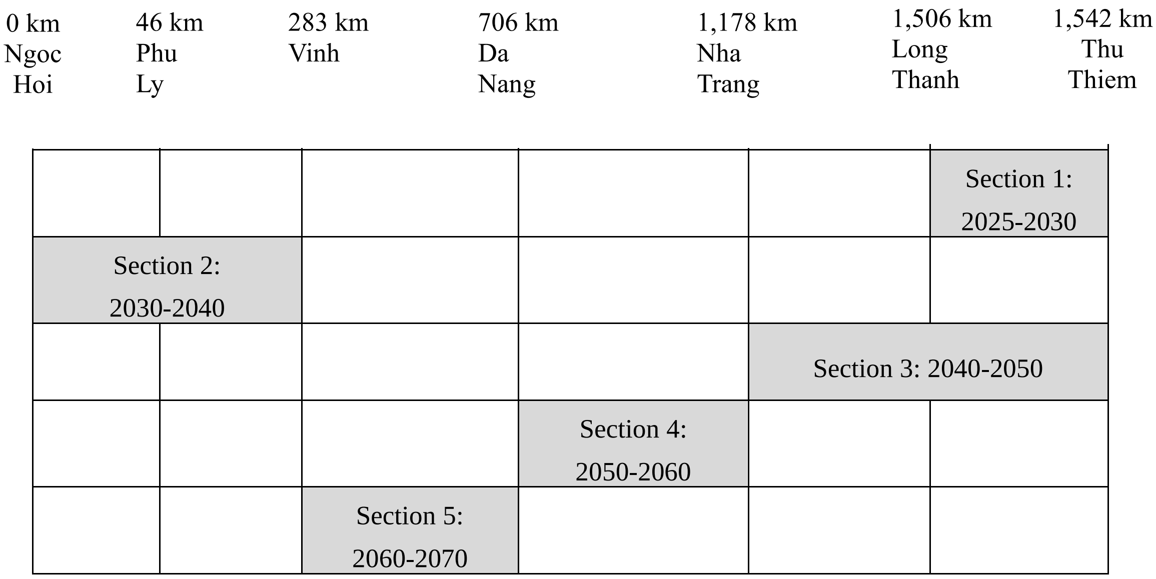
Source: JICA Study Team

(3) Five-step Case

Five-step Case plans to divide the whole line into 5 sections, opening a single-track line between Long Thanh – Thu Thiem by 2030, then Ngoc Hoi – Vinh (283 km) by 2040, Nha Trang – Thu Thiem (364 km) by 2050, Da Nang – Nha Trang (472 km) by 2060, and Vinh – Da Nang (423 km) by 2070.

The Long Thanh – Thu Thiem section is assumed to alleviate the air passenger demand between Long Thanh Airport and HCMC, and reduce the upfront investment costs by applying a single-track line (although this will increase final costs down the line).

The remaining sections shall be prioritized according to demand, and the opening of all lines is assumed to be by 2070.



Source: JICA Study Team

Figure 2.2: Construction Period of Five-step Case

Table 2.2: Outline of Five-step Case

Section	End Points	Distance	Construction Year	Opening	Speed
Section 1: Airport	Ngoc hoi – Vinh	36 km	2025-2030	2030	200 km/h 2040 onwards: 320 km/h
Section 2: North	Ngoc hoi – Vinh	283 km	2030-2040	2040	320 km/h
Section 3: South	Nha Trang – Thu Thiem	364 km	2040-2050	2050	320 km/h
Section 4: Middle South	Da Nang – Nha Trang	472 km	2050-2060	2060	320 km/h
Section 5: Middle North	Vinh – Da Nang	423 km	2060-2070	2070	320 km/h

2.2 Forecast of Transportation Demand

2.2.1 Collection and Updating of Latest Data

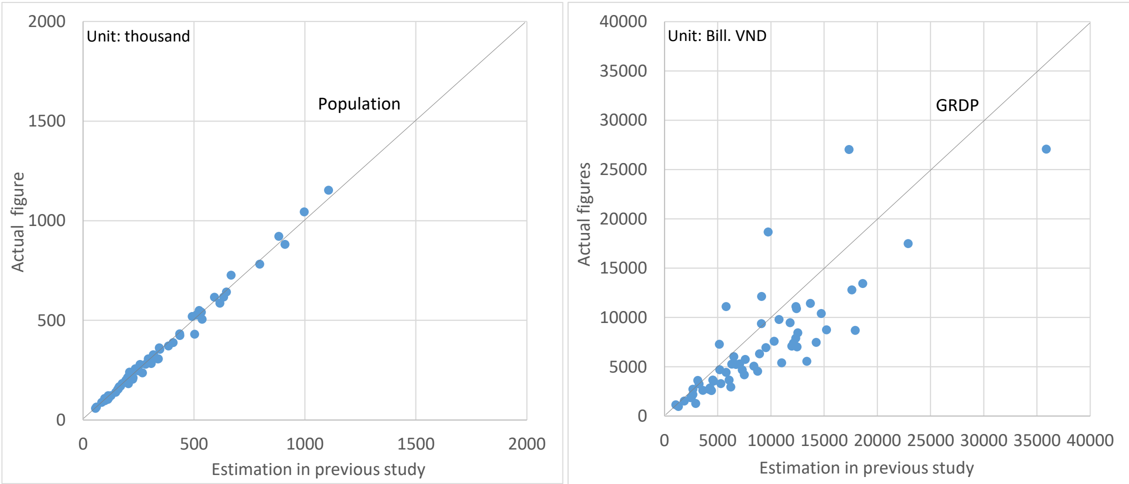
(1) Socio Economic Indicators

The latest information of fundamental data for demand analysis, population and GDP by province, are as shown in the following table. Estimation of the urban population in every province is in line with the figures from the previous study. On the other hand, GDP by province is a little different from the estimation in the previous study.

Table 2.3: Population and GDP by Province in 2010 and 2016

No	Province	2010			2016		
		Population (thousand people)		GDP (bil VND)	Population (thousand people)		GDP (bil VND)
		Urban	Urban area%		Urban	Urban area%	
1	Hà Nội	2827.9	41.0	50,091	3642.2	49.7	79,730
2	Vĩnh Phúc	231.2	22.4	8,589	279.3	26.2	10,892
3	Bắc Ninh	270.2	23.5	6,492	306.4	26.0	18,675
4	Hải Dương	361.5	19.0	8,951	423.2	23.7	11,111
5	Hải Phòng	859.8	46.1	16,327	1043.9	52.7	17,488
6	Hưng Yên	139.6	12.1	6,142	211.8	18.1	6,942
7	Thái Bình	178.5	9.7	7,467	211.2	11.8	7,598
8	Hà Nam	82.2	9.5	3,559	110.1	13.7	4,708
9	Nam Định	326.2	17.6	6,927	370.5	20.0	6,311
10	Ninh Bình	171.2	17.9	4,655	239.2	25.1	4,679
11	Hà Giang	104.7	11.6	1,665	102.8	12.6	1,912
12	Cao Bằng	87.0	16.9	1,991	96.4	18.2	1,284
13	Bắc Kan	48.0	16.1	852	58.1	18.2	977
14	Tuyên Quang	95.4	13.0	2,807	121.2	15.8	2,586
15	Lào Cai	133.3	21.0	1,984	151.9	22.2	3,612
16	Yên Bái	146.7	18.8	2,490	166.4	20.8	2,618
17	Thái Nguyên	293.6	25.6	4,238	326.5	26.6	11,113
18	Lạng Sơn	140.8	19.2	3,045	159.1	20.7	2,852
19	Quảng Ninh	602.1	51.9	9,028	641.7	52.4	11,423
20	Bắc Giang	151.6	9.4	3,980	169.1	10.2	7,284
21	Phú Thọ	240.4	15.8	4,932	236.3	17.1	5,242
22	Điện Biên Phủ	75.2	15.0	1,330	88.1	15.8	1,524
23	Lai Châu	54.1	14.2	725	64.5	14.8	1,142
24	Sơn La	153.4	13.8	2,890	182.4	15.1	3,650
25	Hòa Bình	118.7	15.0	3,569	121.4	14.6	3,299
26	Thanh Hóa	369.3	10.4	13,511	388.1	11.0	13,453
27	Nghệ An	375.4	12.9	10,798	431.7	13.9	10,402
28	Hà Tĩnh	190.8	14.9	4,479	203.9	16.1	3,649
29	Quảng Bình	128.4	15.0	2,435	138.7	15.8	3,264
30	Quảng Trị	170.9	27.4	1,987	213.9	34.3	2,731
31	Thừa Thiên Huế	470.9	36.0	4,144	430.0	37.4	4,429
32	Đà Nẵng	802.4	86.9	7,052	920.7	88.0	9,797
33	Quảng Nam	271.7	18.6	6,079	361.5	24.3	12,141
34	Quảng Ngãi	178.8	14.6	5,804	256.6	20.5	9,376
35	Bình Định	413.8	27.7	6,138	526.0	34.5	68,447
36	Phú Yên	201.2	21.8	3,105	246.4	27.4	3,544
37	Khánh Hòa	518.4	39.9	8,306	616.6	50.8	7,899
38	Kon Tum	150.4	33.5	1,656	239.2	47.1	1,878
39	Gia Lai	382.6	28.6	4,385	518.7	36.6	6,036
40	Dak Lak	421.2	24.0	8,257	549.2	29.3	7,394
41	Dak Nông	75.4	14.7	2,676	107.8	17.8	2,704
42	Lâm Đồng	457.6	37.8	7,623	615.8	47.8	7,104
43	Ninh Thuận	205.2	36.1	1,950	278.4	46.3	2,197
44	Bình Thuận	462.7	39.3	5,105	505.0	41.3	5,755
45	Bình Phước	148.7	16.5	3,913	166.4	17.4	5,271
46	Tây Ninh	167.8	15.6	8,631	208.1	18.6	7,028
47	Bình Dương	503.7	29.9	11,054	726.5	36.4	27,027
48	Đồng Nai	859.6	33.2	24,182	1152.9	38.9	27,079
49	Bà Rịa–Vũng Tàu	504.5	49.9	24,386	585.3	53.6	43,700
50	HCM	6114.3	83.3	103,583	6945.0	83.7	131,925
51	Long An	254.6	17.4	8,368	322.0	21.6	9,476
52	Tiền Giang	246.6	13.7	9,037	308.0	17.7	8,441
53	Bến Tre	125.9	9.9	6,376	155.6	12.3	4,541
54	Trà Vinh	155.2	15.3	5,347	217.5	20.9	4,180
55	Vĩnh Long	158.0	15.3	5,112	198.2	18.9	5,291
56	Đồng Tháp	296.7	17.8	9,341	354.3	21.0	7,477
57	An Giang	640.5	28.4	11,361	781.9	36.2	8,740
58	Kiên Giang	460.1	27.0	12,206	540.1	30.4	12,793
59	Cần Thơ	789.8	65.9	11,737	880.5	70.0	8,692
60	Hậu Giang	161.6	19.6	4,149	181.5	23.5	2,954
61	Sóc Trăng	291.1	19.4	7,420	305.8	23.3	5,413
62	Bạc Liêu	228.6	26.1	5,652	306.6	34.6	5,060
63	Cà Mau	268.5	20.4	9,535	282.4	23.1	5,555

Source: General Statistics Office of Vietnam



Source: JICA Study Team

Figure 2.3: Comparison between Estimate and Actual in Population and GRDP in 2016

Future framework for both indicators, i.e. population and GDP by province, is determined based on the estimation by the Vietnamese government by 2030 and ADB's report. Same urbanized ratio in the previous study to estimate the urban population against the entire provincial population is applied in this study.

Table 2.4: Growing Rate of Population and GDP by Province in the Future

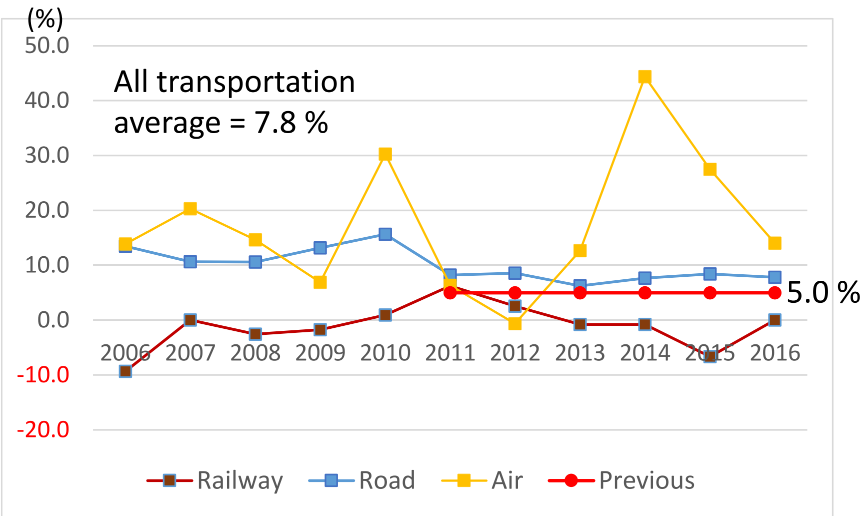
No	Province	Population					GDP				
		2010-15	15-20	20-30	30-40	40-50	2010-15	15-20	20-30	30-40	40-50
1	Hà Nội	4.5	3.2	2.2	1.6	1.1	6.1	6.8	6.1	4.9	3.4
2	Vĩnh Phúc	1.2	3.4	2.4	1.7	1.2	5.7	6.3	5.7	4.5	3.2
3	Bắc Ninh	4.1	3.7	2.6	1.8	1.3	6.3	7.0	6.3	5.0	3.5
4	Hải Dương	3.4	3.2	2.2	1.6	1.1	5.0	5.5	5.0	4.0	2.8
5	Hải Phòng	1.3	2.5	1.8	1.2	0.9	5.2	5.8	5.2	4.2	2.9
6	Hưng Yên	1.7	6.2	4.3	3.0	2.1	6.8	7.6	6.8	5.5	3.8
7	Thái Bình	1.0	4.0	2.8	2.0	1.4	5.0	5.5	5.0	4.0	2.8
8	Hà Nam	8.7	5.9	4.1	2.9	2.0	5.9	6.5	5.9	4.7	3.3
9	Nam Định	0.7	2.8	2.0	1.4	1.0	3.9	4.3	3.9	3.1	2.2
10	Ninh Bình	2.3	4.5	3.2	2.2	1.5	7.0	7.8	7.0	5.6	3.9
11	Hà Giang	2.8	1.1	0.8	0.5	0.4	6.5	7.2	6.5	5.2	3.6
12	Cao Bằng	6.9	2.1	1.5	1.0	0.7	5.9	6.6	5.9	4.8	3.3
13	Bắc Kan	4.1	2.6	1.8	1.3	0.9	6.6	7.3	6.6	5.3	3.7
14	Tuyên Quang	1.5	3.0	2.1	1.5	1.0	7.0	7.8	7.0	5.6	3.9
15	Lào Cai	3.0	2.6	1.8	1.3	0.9	7.0	7.8	7.0	5.6	3.9
16	Yên Bái	2.0	2.0	1.4	1.0	0.7	5.7	6.3	5.7	4.5	3.2
17	Thái Nguyên	7.1	1.3	0.9	0.6	0.4	4.8	5.3	4.8	3.8	2.7
18	Lạng Sơn	1.2	2.2	1.5	1.1	0.8	5.2	5.8	5.2	4.2	2.9
19	Quảng Ninh	4.3	1.2	0.8	0.6	0.4	6.5	7.2	6.5	5.2	3.6
20	Bắc Giang	4.2	1.9	1.3	0.9	0.7	4.0	4.4	4.0	3.2	2.2
21	Phú Thọ	1.2	1.8	1.3	0.9	0.6	4.8	5.3	4.8	3.8	2.7
22	Điện Biên Phủ	1.9	1.9	1.3	0.9	0.7	5.0	5.6	5.0	4.0	2.8
23	Lai Châu	6.3	1.8	1.3	0.9	0.6	5.9	6.5	5.9	4.7	3.3
24	Sơn La	1.1	2.4	1.7	1.2	0.8	7.0	7.8	7.0	5.6	3.9
25	Hòa Bình	0.2	1.0	0.7	0.5	0.3	6.1	6.8	6.1	4.9	3.4
26	Thanh Hóa	8.5	1.6	1.1	0.8	0.5	5.0	5.5	5.0	4.0	2.8
27	Nghệ An	4.3	2.5	1.8	1.2	0.9	4.8	5.3	4.8	3.8	2.7
28	Hà Tĩnh	3.6	2.7	1.9	1.3	0.9	4.7	5.2	4.7	3.7	2.6
29	Quảng Bình	5.9	2.3	1.6	1.1	0.8	4.4	4.9	4.4	3.5	2.5
30	Quảng Trị	1.2	3.2	2.2	1.6	1.1	4.5	5.0	4.5	3.6	2.5
31	Thừa Thiên Huế	3.3	1.1	0.8	0.5	0.4	5.1	5.7	5.1	4.1	2.9
32	Đà Nẵng	2.2	1.6	1.1	0.8	0.5	6.6	7.3	6.6	5.3	3.7
33	Quảng Nam	5.6	4.0	2.8	2.0	1.4	6.3	7.0	6.3	5.0	3.5
34	Quảng Ngãi	2.9	4.7	3.3	2.3	1.6	7.0	7.8	7.0	5.6	3.9
35	Bình Định	2.7	3.6	2.5	1.8	1.2	4.8	5.3	4.8	3.8	2.7
36	Phú Yên	5.0	3.7	2.6	1.8	1.3	6.1	6.8	6.1	4.9	3.4
37	Khánh Hòa	0.9	3.4	2.4	1.7	1.2	6.1	6.8	6.1	4.9	3.4
38	Kon Tum	3.2	5.7	4.0	2.8	2.0	6.1	6.8	6.1	4.9	3.4
39	Gia Lai	1.7	4.3	3.0	2.1	1.5	6.1	6.8	6.1	4.9	3.4
40	Dak Lak	1.4	3.7	2.6	1.8	1.3	5.9	6.6	5.9	4.8	3.3
41	Dak Nông	3.5	4.4	3.1	2.2	1.5	7.0	7.8	7.0	5.6	3.9
42	Lâm Đồng	1.6	4.4	3.1	2.2	1.5	7.0	7.8	7.0	5.6	3.9
43	Ninh Thuận	1.0	3.8	2.7	1.9	1.3	4.8	5.3	4.8	3.8	2.7
44	Bình Thuận	0.6	2.5	1.8	1.2	0.9	6.1	6.8	6.1	4.9	3.4
45	Bình Phước	7.1	1.6	1.1	0.8	0.5	7.5	8.3	7.5	6.0	4.2
46	Tây Ninh	4.8	4.9	3.4	2.4	1.7	5.7	6.3	5.7	4.5	3.2
47	Bình Dương	24.2	4.8	3.4	2.4	1.6	7.0	7.8	7.0	5.6	3.9
48	Đồng Nai	3.2	4.3	3.0	2.1	1.5	6.1	6.8	6.1	4.9	3.4
49	Bà Rịa–Vũng Tàu	1.7	3.4	2.4	1.7	1.2	4.3	4.8	4.3	3.5	2.4
50	HCM	1.6	1.5	1.1	0.7	0.5	5.0	5.6	5.0	4.0	2.8
51	Long An	1.0	3.9	2.7	1.9	1.3	5.3	5.9	5.3	4.2	3.0
52	Tiền Giang	1.5	3.6	2.5	1.8	1.2	5.0	5.6	5.0	4.0	2.8
53	Bến Tre	0.8	4.0	2.8	2.0	1.4	4.9	5.4	4.9	3.9	2.7
54	Trà Vinh	3.4	4.7	3.3	2.3	1.6	5.2	5.8	5.2	4.2	2.9
55	Vĩnh Long	2.2	3.4	2.4	1.7	1.2	5.0	5.5	5.0	4.0	2.8
56	Đồng Tháp	0.2	2.6	1.8	1.3	0.9	6.6	7.3	6.6	5.3	3.7
57	An Giang	0.4	3.7	2.6	1.8	1.3	4.5	5.0	4.5	3.6	2.5
58	Kiên Giang	1.1	2.5	1.8	1.2	0.9	5.7	6.3	5.7	4.5	3.2
59	Cần Thơ	1.1	2.4	1.7	1.2	0.8	6.6	7.3	6.6	5.3	3.7
60	Hậu Giang	3.1	4.0	2.8	2.0	1.4	6.3	7.0	6.3	5.0	3.5
61	Sóc Trăng	6.6	2.6	1.8	1.3	0.9	6.1	6.8	6.1	4.9	3.4
62	Bạc Liêu	0.3	4.3	3.0	2.1	1.5	6.1	6.8	6.1	4.9	3.4
63	Cà Mau	0.5	2.3	1.6	1.1	0.8	5.2	5.8	5.2	4.2	2.9
	Total	3.2	3.1	1.6	1.5	1.1	5.6	5.4	5.6	4.5	3.2

Source: JICA Study Team

(2) Passenger and Freight by Transportation Mode

1) Passengers

The average annual increase rate for passengers of all transportation modes from 2006 to 2016 is 7.8% higher than the expected figures defined in the previous study reported in 2013. Recent increase in aviation is much higher while railways show a negative growth compared to the expected rate. Therefore, trip volume of the updated base OD table mentioned in the next chapter is estimated higher than the estimated OD table in the previous study.

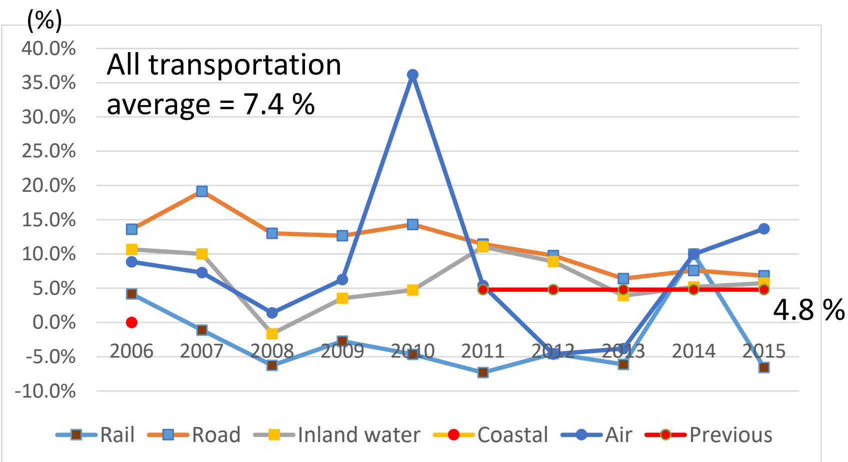


Source: Transport Statistical Yearbook 2016

Figure 2.4: Actual Annual Increase Rate of Passenger by Transportation Mode in Vietnam

2) Freight

The average annual increase rate for freight of all transportation modes from 2006 to 2016 is 7.4% higher than expected figures defined in the previous study report in 2013. Freight movement of the updated OD table mentioned in the next chapter is also more than the estimated OD table in the previous study.



Source: Transport Statistical yearbook 2016

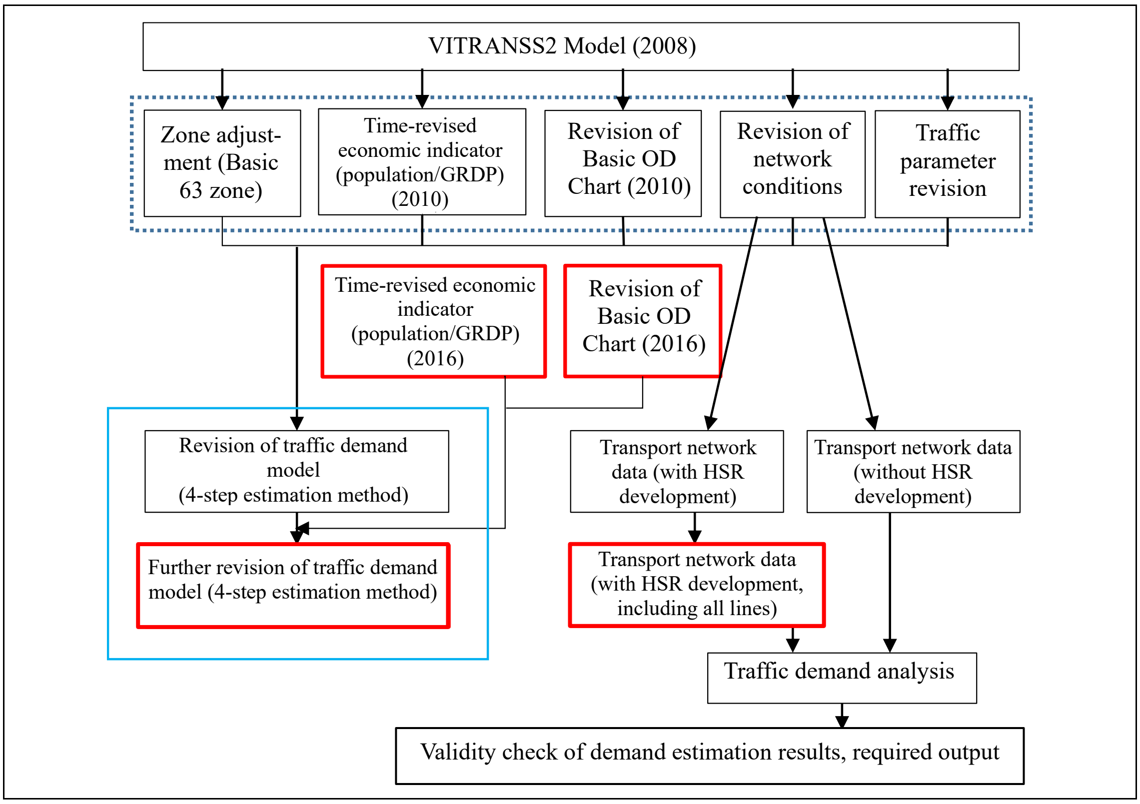
Figure 2.5: Actual Annual Increase Rate of Freight by Transportation Mode in Vietnam

2.2.2 Methodology of Forecasting

(1) Overview

In the previous study, an updated traffic demand model prepared at VITRANSS22 (held in 2008) was used. For the basic traffic model for this survey, VITRANSS2 was used and updated in the same manner as the previous study, and analysis will be carried out based on the time-modified model. Using this method, an efficient analysis may be executed within a limit period of time. Moreover, because consistency with the previous study is assured, it is possible to make comparisons with the results of the previous study.

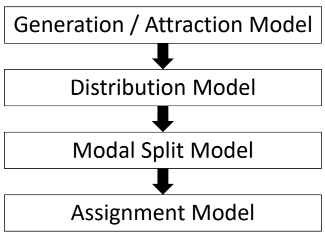
The overall flow related to the demand estimate is shown in the following diagram. The main updated points have been marked with a red border. In proceeding with the analysis, newly-defined or changed conditions in this survey are summarized in the chart below.



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

Figure 2.6: Methodology Flow of Revision for Traffic Demand Analysis in this Study

Flowchart of four step estimation method, which is widely applied for demand analysis and fundamental part of demand forecast, is as shown in the figure below. Each detailed methodology and formula will be stipulated from the next section. Traffic assignment model is not adopted in this study since detailed evaluation for other transportation modes except high speed rail was not considered.



Source: JICA Study Team

Figure 2.7: Four Step Estimation Method for Demand Forecasting

(2) Generation/Attraction Model

Generation/attraction model for every province is defined as following, which is typical and calculated with the same formula using the population and economic factors as the previous study. Regression analysis was applied to estimate the updated coefficients as explanatory variables, i.e. population and GDP per capita by province in 2016 shown in the previous section.

$$G_i \text{ or } A_i = \alpha\, POP_i^{\beta} \cdot (GRDP_i)^{\gamma}$$

Gi (Ai) : Trip Generation (Attraction) of Zone i
POPi: Urban population of Zone i
GRDPi: GRDP per capita of Zone i
α, β, γ: Coefficient

Table 2.5: Trip Generating/Attraction Model

Variable	Model	
	Coefficient	T value
Coefficient Log_e α	-14216.8	-1.6
Urban population β	48.4	12.9
GRDP (per capita) γ	589.8	1.8
Number of samples	63	

Source: JICA Study Team

(3) Distribution Model

Same formula as the Previous Study was assumed for both directions, shown as follows. The trip pattern is estimated using a typical model, which is a kind of gravity model based on a theory that the trip volume is in inverse proportion to the physical distance between two locations.

$$T_{ij} = \frac{C \times G_i^{\alpha} \times A_j^{\beta} \times (dum)^{\delta}}{GC_{ij}^{\gamma}}$$

Where,
Tij: Number of trips between Zone i and j
Gi : Average of trips generation of zone i
Aj: Average of trips attraction of zone j
*GCij: (time)*VoT + (cost)*
C: Constant
dum: Dummy constant
α, β, γ and δ: Parameters

Table 2.6: Distribution Model

Variable	Coefficient	t-Value
Constant	1.8244	5.51
Generation	0.4020	18.82
Attraction	0.4020	18.82
Generalized Cost	0.8712	36.31
Dummy	1.6350	36.68
Multiple Correlation Coefficient	0.8318	
Number of Samples	1678	

Source: Previous Study (JICA, 2013)

(4) Modal Split Model

1) Overview

Modal split model, aggregate logit model, defined in the previous study in 2013 is applied in this study as well. The typical formula and each parameter are as shown below. Modal choice is determined by factors of time and cost by individuals. Also, certain dummy variables are considered for modal choice of Rail, Air, and HSR since personal income factor may affect modal choice behavior according to the revenue changes in future. The model was separated into three types, according to the area categories (Area 1 – Area 3), which shows area economical characteristics.

$$P_i = \frac{exp(V_i)}{exp(V_1)+exp(V_2)+exp(V_3)+exp(V_4)+exp(V_5)}$$

Where,

Pi: *Modal share of transportation mode i*
Car: $V_1 = a \times Time_1 + b \times Cost_2$
Bus: $V_2 = a \times Time_2 + b \times Cost_2 + const_2$
Rail: $V_3 = a \times Time_3 + b \times Cost_3 + const_3 + d_3 \times (GDP/POP)$
AIR: $V_4 = a \times Time_4 + b \times Cost_4 + const_4 + d_4 \times (GDP/POP)$
HSR: $V_5 = a \times Time_5 + b \times Cost_5 + const_5 + d_5 \times (GDP/POP)$

Parameter	Coefficient		
	Area 1	Area 2	Area 3
a (Time : min)	-0.003132	-0.001443	-0.003056
b(Cost : VND 000)	-0.034587	-0.003893	-0.029576
d3(GDP/POP for Rail)	-0.26627	-0.12791	-0.00914
d4(GDP/POP for HSR)	0.033803	0.002579	0.019464
d5(GDP/POP forAir)	0.037187	0.005432	0.004403
const2(for Bus)	0.34746	0.18298	0.47840
const3(for Rail)	0.64879	0.08124	-0.00044
const4(for HSR)	-0.54423	0.140312	-0.49032
const5(for Air)	-1.48783	0.147549	-0.5237

Source: Previous Study (JICA,2013)

Figure 2.8: Area Type

2) Time and Cost Factors

The following factors are considered as fare and time components for each transportation means. Fare/cost value has been updated using the increase rate of the figures of the previous study. The travel time of road transportation, private cars and buses, is calculated by the minimum time required from area to area, using the existing road network distance. The travel distance of the existing rail and HSR is also adopted by the actual railway network. Flight distance between airports is calculated by the direct distance, based on coordination database.

Table 2.7: Trip Generating/Attraction Model

Mode		Fare/Cost (VND/pax-km)	Onboard time (min)	Access/egress time	Check-in and Waiting time
Car	Road	629 *1	Distance / avg. speed 40km/h	0 min	0 min
	Expressway	1,021 *1	Distance / avg. speed 80km/h		
Bus	Road	627 *1	Distance / avg. speed 32km/h	20 min	20 min
	Expressway	780 *1	Distance / avg. speed 64km/h		
Existing Rail		698 *1	Distance / avg. speed 60km/h	20 min	20 min
High Speed Rail (HSR)		900 *2	Distance / avg. speed 280km/h	According to distance between nearest HSR st. and zone center	20 min
Air		1,445 *3	Distance / avg. speed 600km/h	According to distance between nearest Airport and zone center	60 min

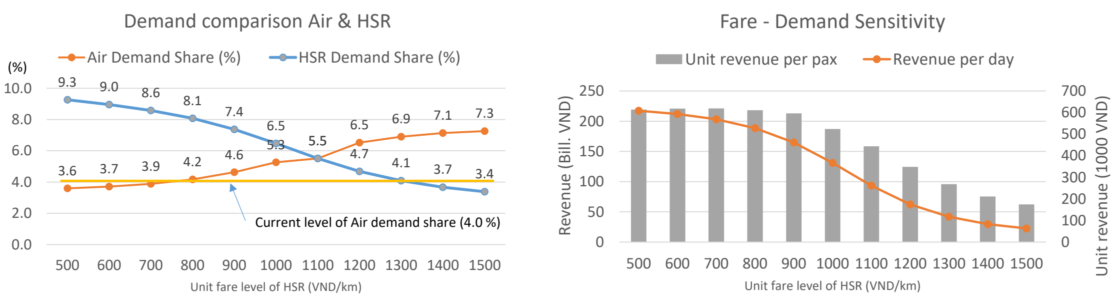
*1 consideration economic growth, *2 consideration optimal fare revenue & air,
*3 consideration rapid growing of LCC

Source: JICA Study Team

3) HSR Fare Sensitivity

HSR's appropriate fare shall be determined from various aspects, such as competitiveness for other transportation and etc., otherwise, on political issues. Fare sensitivity analysis between the balance of HSR transportation usage and air has been conducted. For the time being, HSR fare unit is set at 900 VND / km, in consideration of the total HSR revenue earned and trip share to make air transportation sustainable.

The current air demand share in Vietnam is 4.0% in 2016 and the HSR fare level to at least keep the constant air modal share is assumed to be more than 800 VND/km. On the other hand, the 900 VND/km unit fare level of HSR is at the borderline to maintain an effective unit (average) revenue per passenger, which is also an index to show the average trip length of passengers. Much of the passengers who travel a long distance would shift from HSR to other transportation modes in case the unit fare level is set at over 900 VND/km.

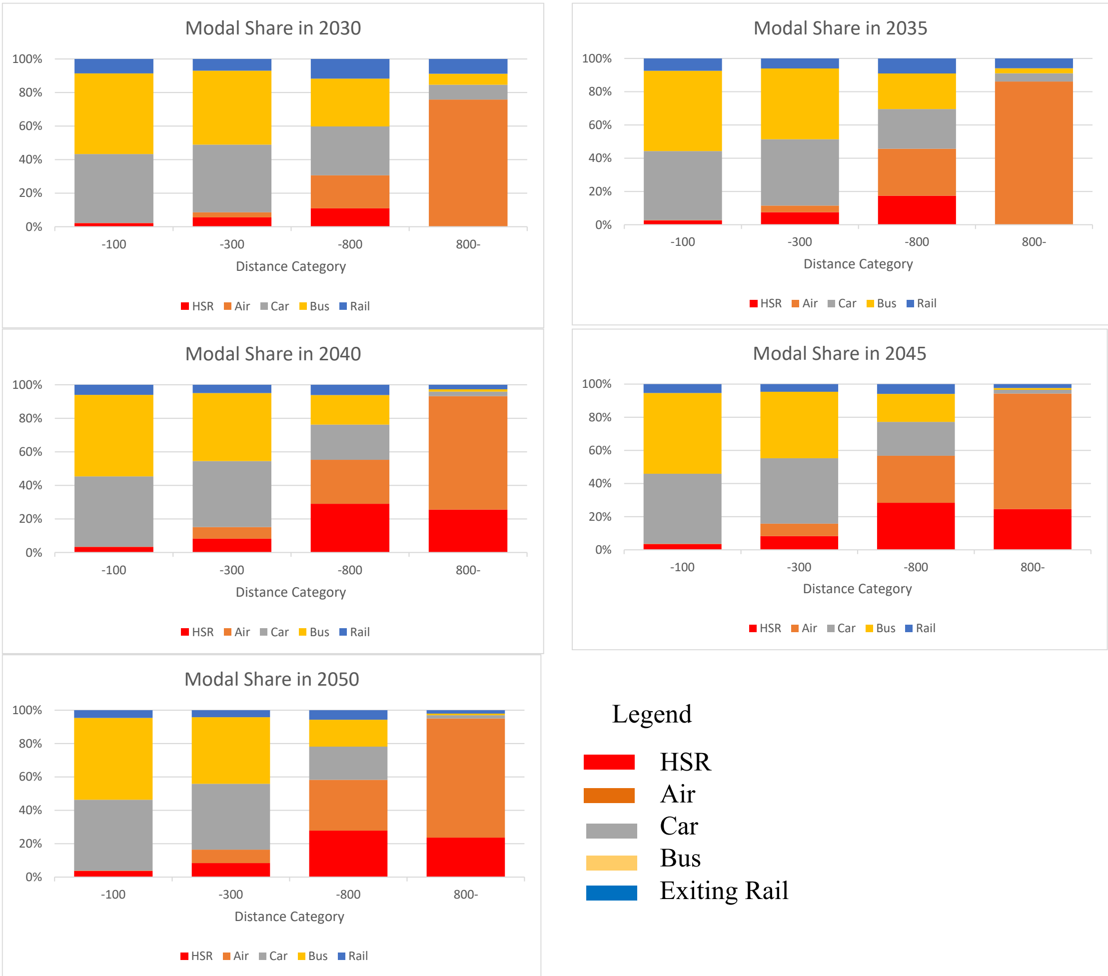


Source: JICA Study Team

Figure 2.9: HSR Fare Sensitivity Analysis

4) General Features on Transportation Model Split

Transportation modal split for every target year is summarized in below figure by distance categories, i.e. within 100 km, 100 – 300 km, 300 – 800 km, and over 800 km band. According to the simulation, the HSR system has an advantage for the middle range distance, 300 km – 800 km, against other transportation modes. However, for the tentative construction stage in 2030 and 2035, this is not applied since the longest distance of the HSR mode is around 400 km at the North and South section in Vietnam.



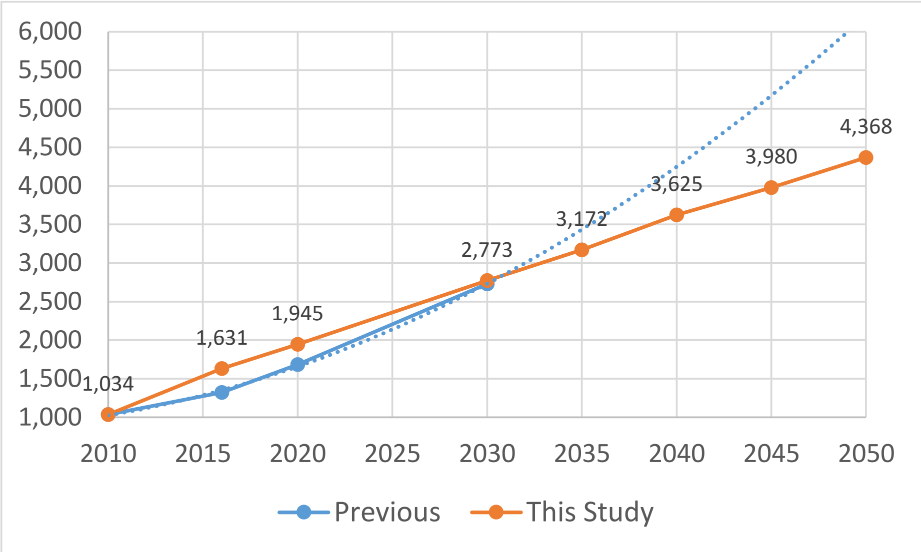
Source: JICA Study Team

Figure 2.10: Modal Split by Distance Category by Transportation Modes

2.2.3 Updated OD Matrix

(1) Passengers

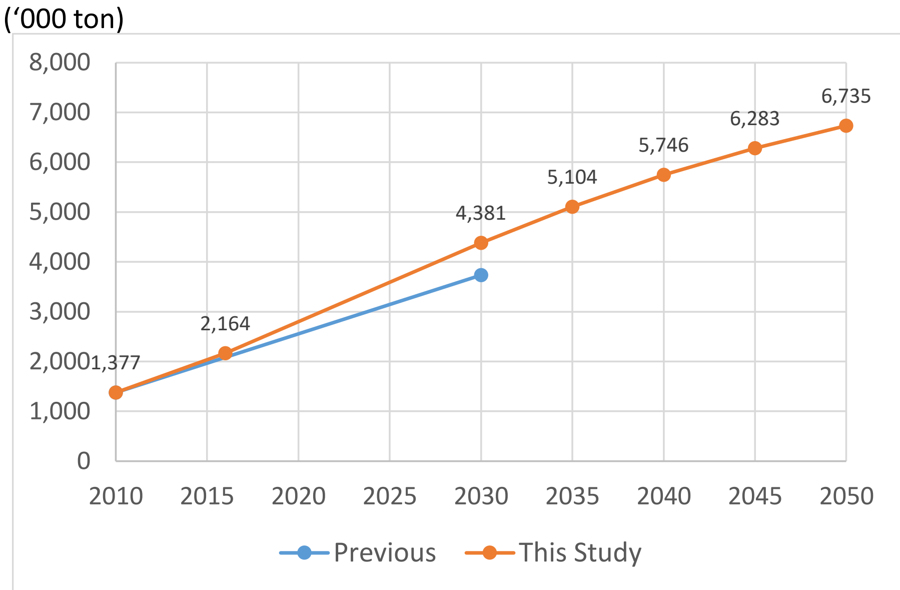
The summary of the updated OD matrix in the future target year is shown in the following figure. The total trip volume in each target year is gradually increased for the base OD case in 2016. The trip volume up to 2030 is much higher than the estimation in the previous study since the actual transportation volume up to now is larger. However, the trend of the increasing trip volume beyond around 2030 is slower compared to the previous estimation.



Source: JICA Study Team

Figure 2.11: Total Passenger Trip Demand in Every Target Years in Vietnam

(2) Freight



Source: JICA Study Team

Figure 2.12: Total Freight Demand in each Target Year in Vietnam

2.2.4 Update on the Current Status and Planning of the Transport System in the Target Area

(1) Long Thanh International Airport

The new international airport, Long Thanh International Airport, for the HCMC area has been planned at Dong Nai province 50 km away of the CBD Ho Chi Minh, due to the rapid passenger and freight volume increase of the existing Tansonnhat International Airport. Operation is planned to be started around 2025 in phase 1 stage and to cover 100 million passengers per year, in the final stage completion. The existing Tansonnhat Airport in the CBD will be also operated with supplemental functions to the new international airport.

According to the feasibility study conducted by JICA, the capacity of the terminal and expected passenger volume are as follows,

Table 2.8: Expected Airport User Demand in HCMC Area

Year	Passenger per year (thousand)
2020	25,000
2030	44,000

Source: Vietnam Business Vol. 23 (Lai Vien Co., Ltd, 2012)[1]

Table 2.9: Development Phase and Capacity of New Airport

Phase	Opening year	Capacity	
		Passenger per year (thousand pax/day)	Freight (thousand ton/day)
Phase 1	2025	25,000	770
Phase 2	2035	52,000	1,400
Phase 3	Beyond 2035	100,000	5,000

Source: Vietnam Business Vol. 23 (Lai Vien Co., Ltd, 2012)

New HSR station at the Long Thanh International Airport is planned specifically for new airport users. Some airport users may access the new airport via HSR usage instead of other existing transportation modes. These potential passenger volume of HSR shall be considered since international flight passengers are not included in the estimated domestic trip OD matrix. Therefore, the HSR passenger volume using the section between HCMC and Long Thanh is estimated through the following assumptions and framework.

Table 2.10: Development Phase and Capacity of New Airport

Year	Demand in HCMC area (thousand pax / year)	Tansonnhat		Long Thanh	
		Capacity (thousand pax / year)	Demand (thousand pax / year)	Capacity (thousand pax / year)	Demand (thousand pax / year)
2030	44,000	20,000	20,000	25,000	24,000
2035	56,000	20,000	20,000	52,000	36,000
2040	72,000	20,000	20,000	52,000	52,000
2045	87,000	20,000	20,000	100,000	67,000
2050	106,000	20,000	20,000	100,000	86,000

Source: JICA Study Team

(2) Existing Railway Improvement

There is an improvement/rehabilitation plan for the existing railway infrastructure in Vietnam. However, the final development policy is not fixed yet. The improvement program for the existing railway would impact the HSR project, and it should be considered as an affiliated project to the HSR project. Therefore, the improvement of the existing railway is analyzed as a scenario setting and appropriate improvement case will be proposed as recommendation in this study.

[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)

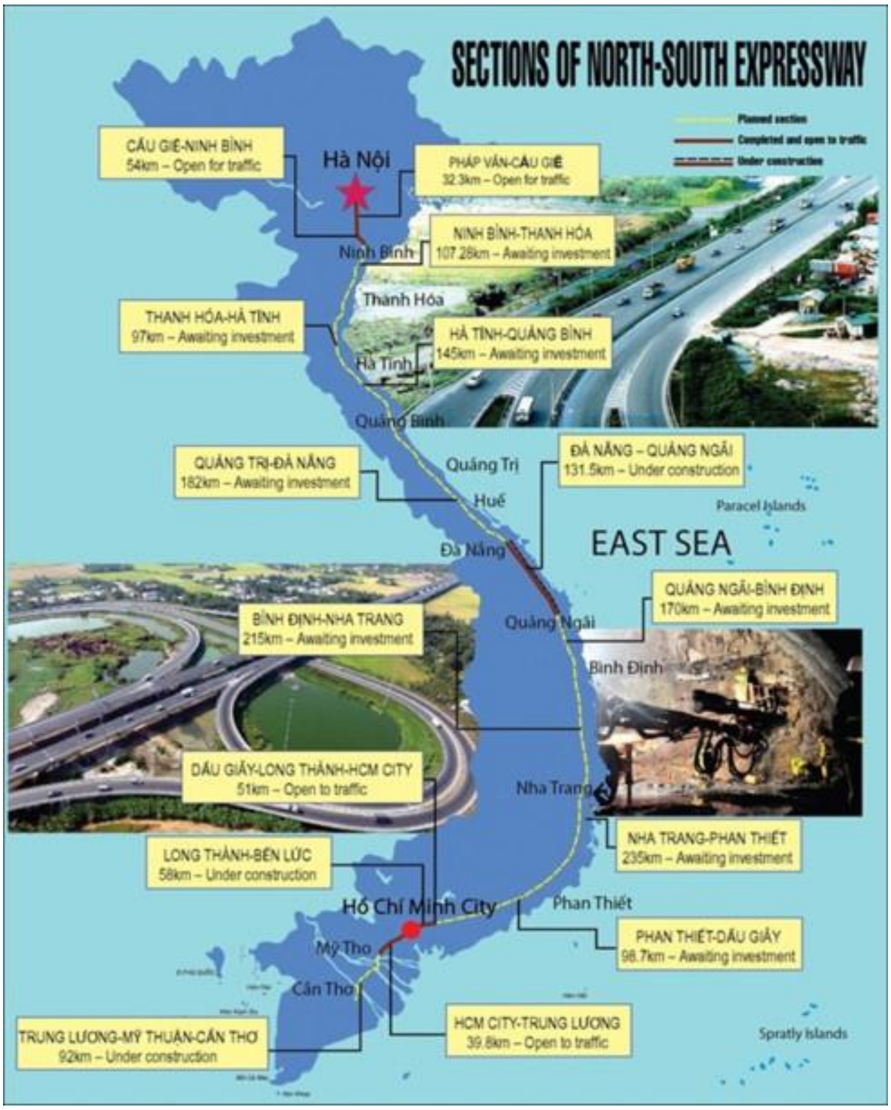
(3) North-South Arterial Roads

Four (4) major arterial roads are considered as the main access corridor between Hanoi and Ho Chi Minh in the future. The type of roads includes the "Expressway," "National Highway No. 1", "Coastal roads," and "Hanoi – Ho Chi Minh roads (upgrade of several national roads)." Only a section of the expressway, i.e. Hanoi – Ninh Binh and surrounding Ho Chi Minh, is under operation and others are still under construction or planning. The outline of the plans of each corridor is as follows, based on the road development strategy and relevant information. The detailed information on the capacity of the roads is mentioned in Chapter 2.2.6.

Table 2.11: Outline of Main Access Corridor between Hanoi and Ho Chi Minh

Name of roads	Number of lanes	Opening year	Remarks
Expressway	4	Operation	Temporary opening
National Highway No. 1	4 – 8	2030	
Coastal road	2	2030	
Hanoi – Ho Chi Minh road	4	2030	

Source: The local consultants



Source: MOT, Vietnam reference

Figure 2.13: North-South Expressway in Vietnam

2.2.5 Forecasting Scenarios (Two-step Case)

(1) Improvement for Railway Infrastructure

The Vietnamese side has considered the improvement of the railway infrastructure referring to suggestions in VITRANSS2 and the Previous Study on HSR. Basically, there are two types of improvements for railway infrastructure, i.e. improvement of the existing railway or development of new additional tracks to enhance the capacity of the railway transport sector. The four improvement levels for the existing railways are shown below.

Opening year of HSR as temporary operation is in 2030 for section of "Hanoi – Vinh" and "Nha Trang – Ho Chi Minh" and full operation for all sections is in 2040. Target years to estimate volume and make analysis are 2030 (temporary opening year), 2035, 2040 (full operation year), 2045, and 2050.

Table 2.12: Development Levels for Existing Railway and HSR

	Level	Description
Existing Railway	A1	Single Track, 1,000 mm, 60 km/h
	A2	Single Track, 1,000 mm, 70 km/h
	B1	Double Track, 1,000 mm, 120 km/h
	B2	Double Track, 1,435 mm, 200 km/h [2]
HSR	H1	Max. Operation Speed 200 km/h, Freight & Passenger Only
	H2	Max. Operation Speed 320 km/h, Passenger Only

Source: JICA Study Team

(2) Development Scenario (Mix Development for Existing Railway and HSR)

Based on discussions with the local consultants, three (3) development scenarios shown in Table 2.13 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 320 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.

Table 2.13: Development Scenario on Existing Railway and HSR

Scenario	Existing Railway	HSR
1	A2	N/A
2	B2	N/A
3	A2	H2

Source: JICA Study Team

[2] In the previous study, the maximum speed at B2 level was 150 km/h, but in this research, demand forecast was conducted assuming that the operation speed at B2 level is 200 km h based on consultations with the local consultants.

2.2.6 Forecast Results (Two-step Case)

(1) Total Passenger Potential Demand

Demand forecast results of the proposed scenarios by target year are summarized in the below table. The share of the HSR transportation for all modes is around 7%, which is equivalent to around 300,000 passengers per day when the entire line is developed, from Hanoi to HCMC.

Table 2.14: Passenger Demand Results by Transportation Modes for each Scenario

Unit: Pax/day

	No	Year	Car	Bus	Existing Rail (A2)	HSR	Air line	Total
Senario 1	1	2030	1,061,100	1,208,277	338,557	0	164,661	2,772,595
	2	2035	1,231,583	1,386,642	326,454	0	227,689	3,172,368
	3	2040	1,423,610	1,593,221	321,018	0	287,144	3,624,993
	4	2045	1,576,057	1,757,671	312,493	0	333,444	3,979,665
	5	2050	1,744,390	1,939,514	300,073	0	384,322	4,368,299
	No	Year	Car	Bus	Existing Rail (B2)	HSR	Air line	Total
Senario 2	1	2030	1,039,905	1,185,472	442,347	0	104,871	2,772,595
	2	2035	1,210,200	1,364,512	444,410	0	153,246	3,172,368
	3	2040	1,401,584	1,570,765	449,209	0	203,435	3,624,993
	4	2045	1,553,804	1,735,152	446,522	0	244,187	3,979,665
	5	2050	1,722,127	1,917,124	438,972	0	290,076	4,368,299
	No	Year	Car	Bus	Existing Rail (A2)	HSR	Air line	Total
Senario 3	1	2030	1,030,073	1,174,277	322,225	84,120	162,036	2,772,730
	2	2035	1,181,892	1,333,658	301,567	133,040	222,909	3,173,066
	3	2040	1,363,484	1,528,882	271,871	279,394	176,835	3,620,465
	4	2045	1,503,131	1,684,721	264,001	303,353	221,149	3,976,355
	5	2050	1,666,249	1,856,206	251,929	330,811	257,377	4,362,571

Unit: %

	No	Year	Car	Bus	Existing Rail (A2)	HSR	Air line	Total
Senario 1	1	2030	38.3%	43.6%	12.2%	0.0%	5.9%	100.0%
	2	2035	38.8%	43.7%	10.3%	0.0%	7.2%	100.0%
	3	2040	39.3%	44.0%	8.9%	0.0%	7.9%	100.0%
	4	2045	39.6%	44.2%	7.9%	0.0%	8.4%	100.0%
	5	2050	39.9%	44.4%	6.9%	0.0%	8.8%	100.0%
	No	Year	Car	Bus	Existing Rail (B2)	HSR	Air line	Total
Senario 2	1	2030	37.5%	42.8%	16.0%	0.0%	3.8%	100.0%
	2	2035	38.1%	43.0%	14.0%	0.0%	4.8%	100.0%
	3	2040	38.7%	43.3%	12.4%	0.0%	5.6%	100.0%
	4	2045	39.0%	43.6%	11.2%	0.0%	6.1%	100.0%
	5	2050	39.4%	43.9%	10.0%	0.0%	6.6%	100.0%
	No	Year	Car	Bus	Existing Rail (A2)	HSR	Air line	Total
Senario 3	1	2030	37.2%	42.4%	11.6%	3.0%	5.8%	100.0%
	2	2035	37.2%	42.0%	9.5%	4.2%	7.0%	100.0%
	3	2040	37.7%	42.2%	7.5%	7.7%	4.9%	100.0%
	4	2045	37.8%	42.4%	6.6%	7.6%	5.6%	100.0%
	5	2050	38.2%	42.5%	5.8%	7.6%	5.9%	100.0%

Source: JICA Study Team

Based on these potential passenger demand, simple traffic assignment for each transportation, i.e. roads (Car and Buses), existing rail, air, and HSR, is simulated considering every infrastructure capacity. The most critical capacity shortage is found in the existing rail in Scenario 2 mentioned in the previous section, which the traffic above capacity shall be shifted to other transportation modes. Results of sectional demand of each transportation considering the analysis of such supply – demand among modes are shown in section 2.2.7 of this chapter.

Table 2.15: Road Capacity by Target Year

Current			Plan	North		Central			South	
				N1	N2	C1	C2	C3	S1	S2
				Hanoi - Thanh Hoa	Thanh Hoa - Vinh	Vinh - Hue	Hue - Da Nang	Da Nang - Nha Trang	Nha Trang - Phan Thiet	Phan Thiet - HCMC
Roads	# lane	National Highway	4 - 6	4 - 6 (4)	4	4	4	4	4	2 - 4 (4)
		Expressway	4 - 8	0 - 4 (4)	-	-	-	0 - 4 (0)	-	0 - 6 (4)
		Coastal Rd.	2	-	-	-	-	-	-	-
		Hanoi-HCMC Rd.	4	2	2	2	2	2	2	2
	Capacity	National Highway	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Expressway	pcu/day	55,300	-	-	-	-	-	55,300
		Coastal Rd.	pcu/day	-	-	-	-	-	-	-
		Hanoi-HCMC Rd.	pcu/day	12,000	12,000	12,000	12,000	12,000	12,000	12,000
		Total	pcu/day	113,100	57,800	57,800	57,800	57,800	57,800	113,100

2030			Plan	North		Central			South	
				N1	N2	C1	C2	C3	S1	S2
				Hanoi - Thanh Hoa	Thanh Hoa - Vinh	Vinh - Hue	Hue - Da Nang	Da Nang - Nha Trang	Nha Trang - Phan Thiet	Phan Thiet - HCMC
Roads	# lane	National Highway	4 - 6	4	4	4	4	4	4	4
		Expressway	4 - 8	6 - 8 (4)	4	4	4	4	4	4 - 6 (4)
		Coastal Rd.	2	2	2	0 - 2 (0)	2	0 - 2 (0)	-	-
		Hanoi-HCMC Rd.	4	2	2	2	2	2	2	2
	Capacity	National Highway	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Expressway	pcu/day	55,300	55,300	55,300	55,300	55,300	55,300	55,300
		Coastal Rd.	pcu/day	14,600	14,600	-	14,600	-	-	-
		Hanoi-HCMC Rd.	pcu/day	12,000	12,000	12,000	12,000	12,000	12,000	12,000
		Total	pcu/day	127,700	127,700	113,100	127,700	113,100	113,100	113,100

2040～			Plan	North		Central			South	
				N1	N2	C1	C2	C3	S1	S2
				Hanoi - Thanh Hoa	Thanh Hoa - Vinh	Vinh - Hue	Hue - Da Nang	Da Nang - Nha Trang	Nha Trang - Phan Thiet	Phan Thiet - HCMC
Roads	# lane	National Highway	4 - 6	4	4	4	4	4	4	4
		Expressway	4 - 8	6 - 8 (4)	4	4	4	4	4	4 - 6 (4)
		Coastal Rd.	2	2	2	0 - 2 (2)	2	0 - 2 (2)	2	2
		Hanoi-HCMC Rd.	4	4	4	4	4	4	4	4
	Capacity	National Highway	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Expressway	pcu/day	55,300	55,300	55,300	55,300	55,300	55,300	55,300
		Coastal Rd.	pcu/day	14,600	14,600	14,600	14,600	14,600	14,600	14,600
		Hanoi-HCMC Rd.	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Total	pcu/day	161,500	161,500	161,500	161,500	161,500	161,500	161,500

2045～			Plan	North		Central			South	
				N1	N2	C1	C2	C3	S1	S2
				Hanoi - Thanh Hoa	Thanh Hoa - Vinh	Vinh - Hue	Hue - Da Nang	Da Nang - Nha Trang	Nha Trang - Phan Thiet	Phan Thiet - HCMC
Roads	# lane	National Highway	4 - 6	4	4	4	4	4	4	4
		Expressway	4 - 8	6 - 8 (6)	4	4	4	4	4	4 - 6 (6)
		Coastal Rd.	2	2	2	0 - 2 (2)	2	0 - 2 (2)	2	2
		Hanoi-HCMC Rd.	4	4	4	4	4	4	4	4
	Capacity	National Highway	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Expressway	pcu/day	93,550	93,550	55,300	55,300	55,300	55,300	93,550
		Coastal Rd.	pcu/day	14,600	14,600	14,600	14,600	14,600	14,600	14,600
		Hanoi-HCMC Rd.	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Total	pcu/day	199,750	199,750	161,500	161,500	161,500	161,500	199,750

2050～			Plan	North		Central			South	
				N1	N2	C1	C2	C3	S1	S2
				Hanoi - Thanh Hoa	Thanh Hoa - Vinh	Vinh - Hue	Hue - Da Nang	Da Nang - Nha Trang	Nha Trang - Phan Thiet	Phan Thiet - HCMC
Roads	# lane	National Highway	4 - 6	4	4	4	4	4	4	4
		Expressway	4 - 8	6 - 8 (6)	6	4	4	4	4	4 - 6 (6)
		Coastal Rd.	2	2	2	0 - 2 (2)	2	0 - 2 (2)	2	2
		Hanoi-HCMC Rd.	4	4	4	4	4	4	4	4
	Capacity	National Highway	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Expressway	pcu/day	93,550	93,550	55,300	55,300	55,300	55,300	93,550
		Coastal Rd.	pcu/day	14,600	14,600	14,600	14,600	14,600	14,600	14,600
		Hanoi-HCMC Rd.	pcu/day	45,800	45,800	45,800	45,800	45,800	45,800	45,800
		Total	pcu/day	199,750	199,750	161,500	161,500	161,500	161,500	199,750

Source: The local consultants

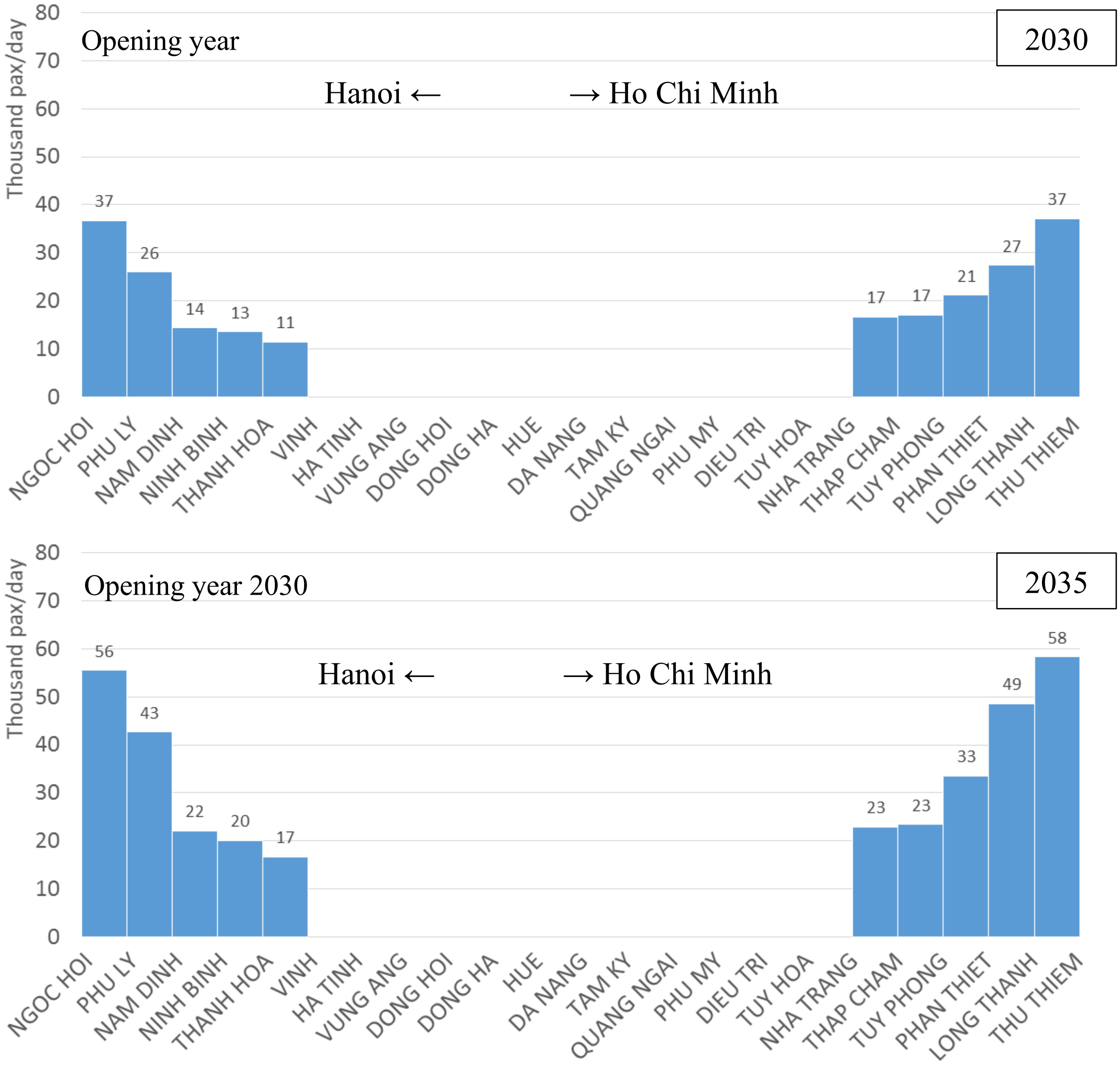
Table 2.16: Other Transportation Capacity

Transportation modes	Description	Capacity		
		Number of train sets /flight		Passengers per train/flight
Existing Rail	Single Track (A1)	32	train/day	600 pax / train
	Single Track (A2)	50	train/day	600 pax / train
	Double Track (B1, B2)	170	train/day	600 pax / train
HSR	Passenger Only (H2)	300	train/day	740 pax / train (- 2040)
				1220 pax / train (2040 -)
Air	Hanoi side	366	flight/day	Average 264 seats / flight
	HCMC side	492	flight/day	Average 264 seats / flight

Source: The local consultants

(2) Sectional Demand

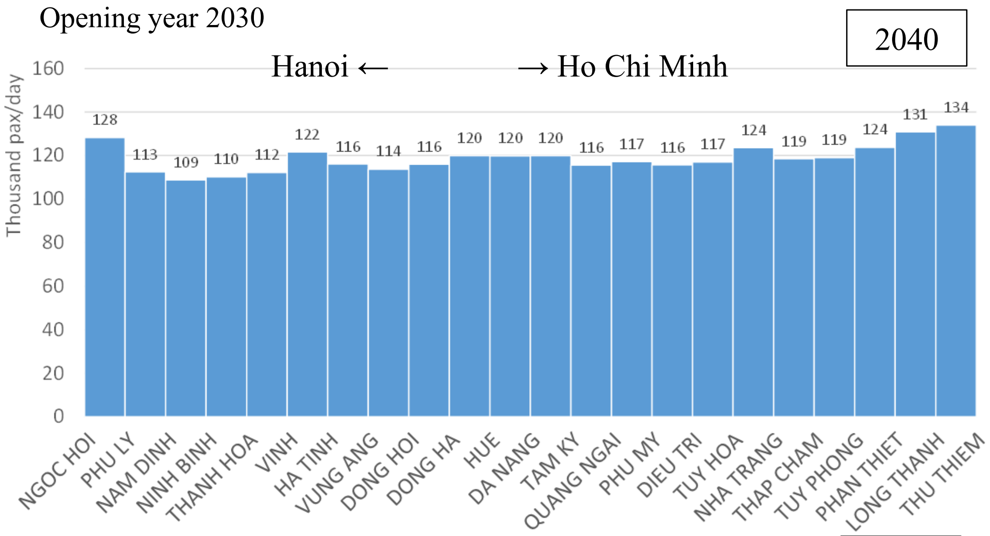
Sectional demand (both directions) of HSR at each target year is as shown below. The passenger volume of the north section, Hanoi – Vinh, and south section, Nha Trang – HCMC, are almost at the same level. One of the features of the north section, however, is the high volume of short trips around Hanoi, which seems to be usage by commuting passengers.

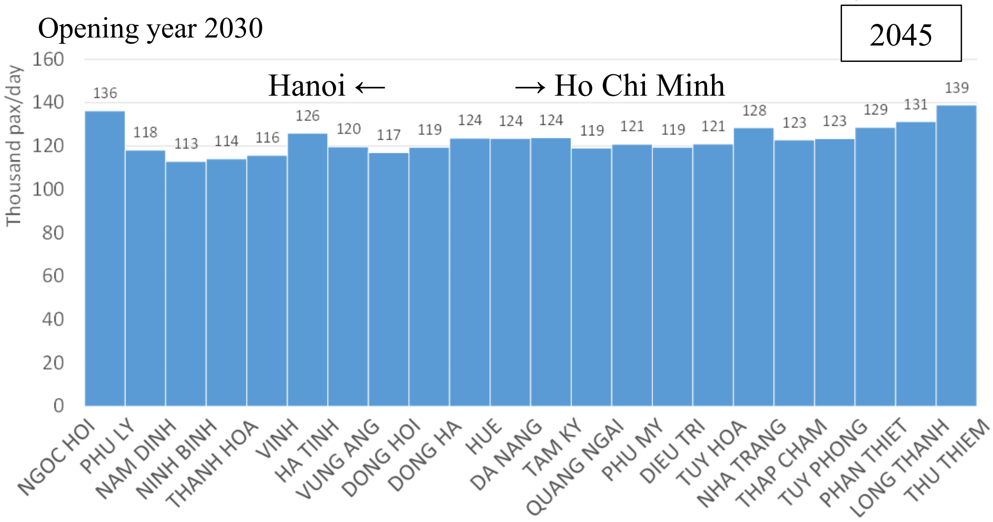


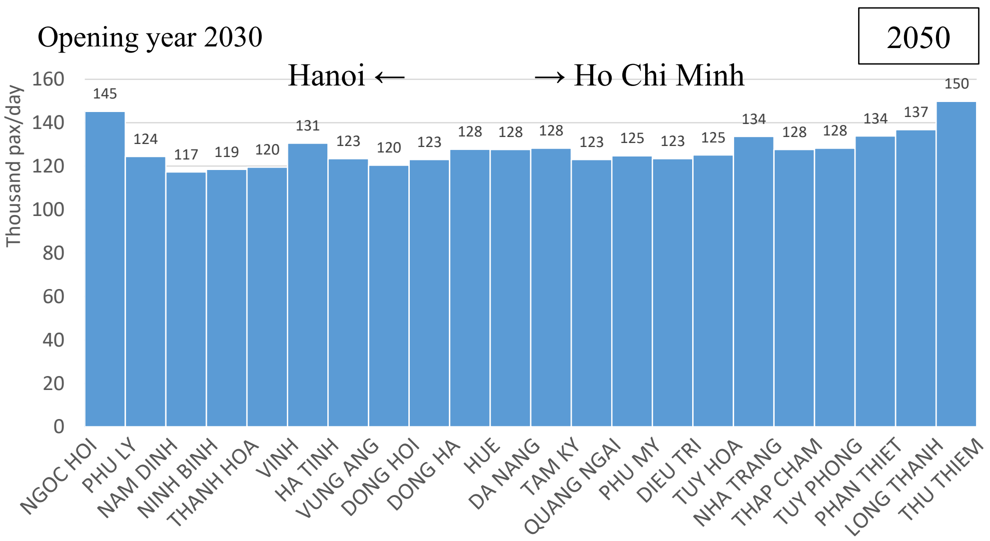
Source: JICA Study Team

Figure 2.14: Number of Passenger at Every HSR Section (2030 and 2035)

On the other hand, the sectional passenger volume after the full development of HSR in 2040 will be drastically increased, since the majority of HSR passengers are long distance trip users, compared to other transportation modes. Especially the passenger shares between Hanoi and HCMC is much higher than the other trip patterns, so every sectional demand show similar results.







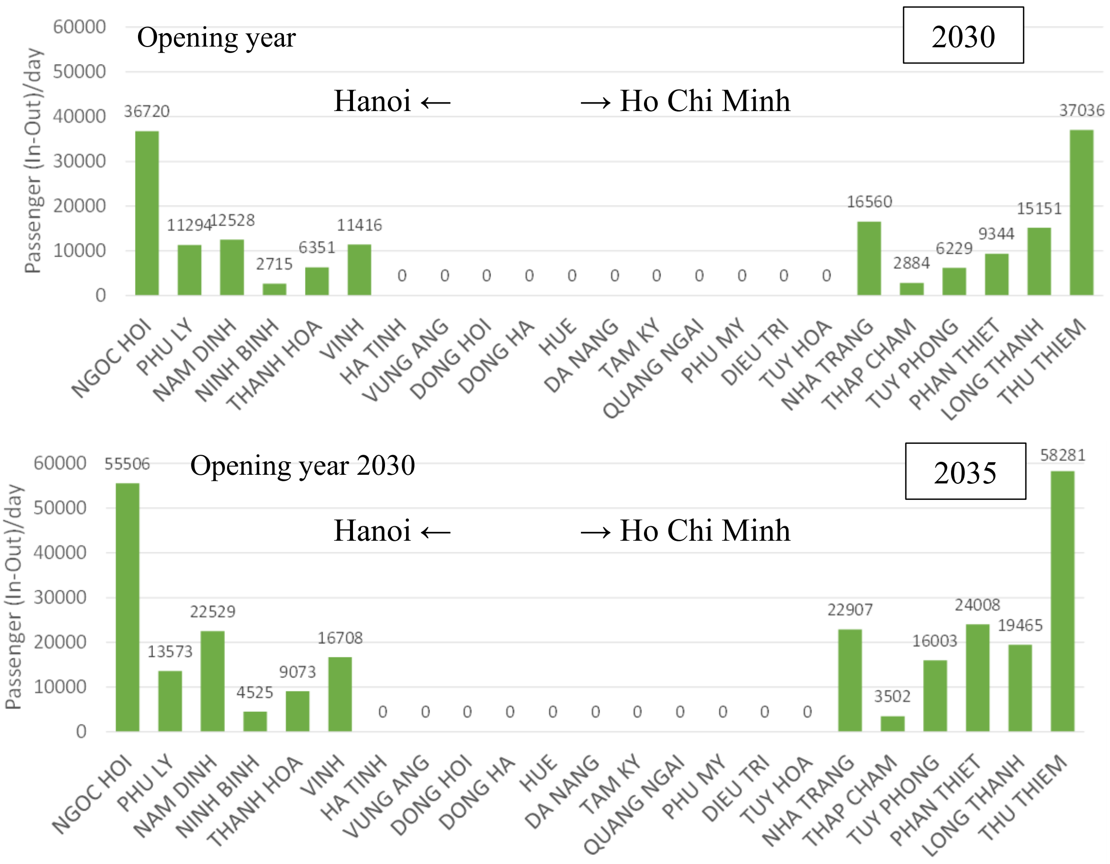
Source: JICA Study Team

Figure 2.15: Number of Passenger at Every HSR Section (2040, 2045, and 2050)

(3) Passenger Demand at Proposed Stations

The passenger demand (both directions) at proposed stations of each target year is as shown below. The number of passengers of HSR Thu Thiem (HCMC) station is expected to be more than 37,000 passengers at the temporary stage of 2030. The second largest HSR station in terms of passenger volume is expected to be Hanoi. The passenger volume of Phu Ly st., Nam Dinh st., Vinh st., Nha Trang st., and Long Thanh st. are ranked third onwards, with more than 10,000 passengers per day in 2030.

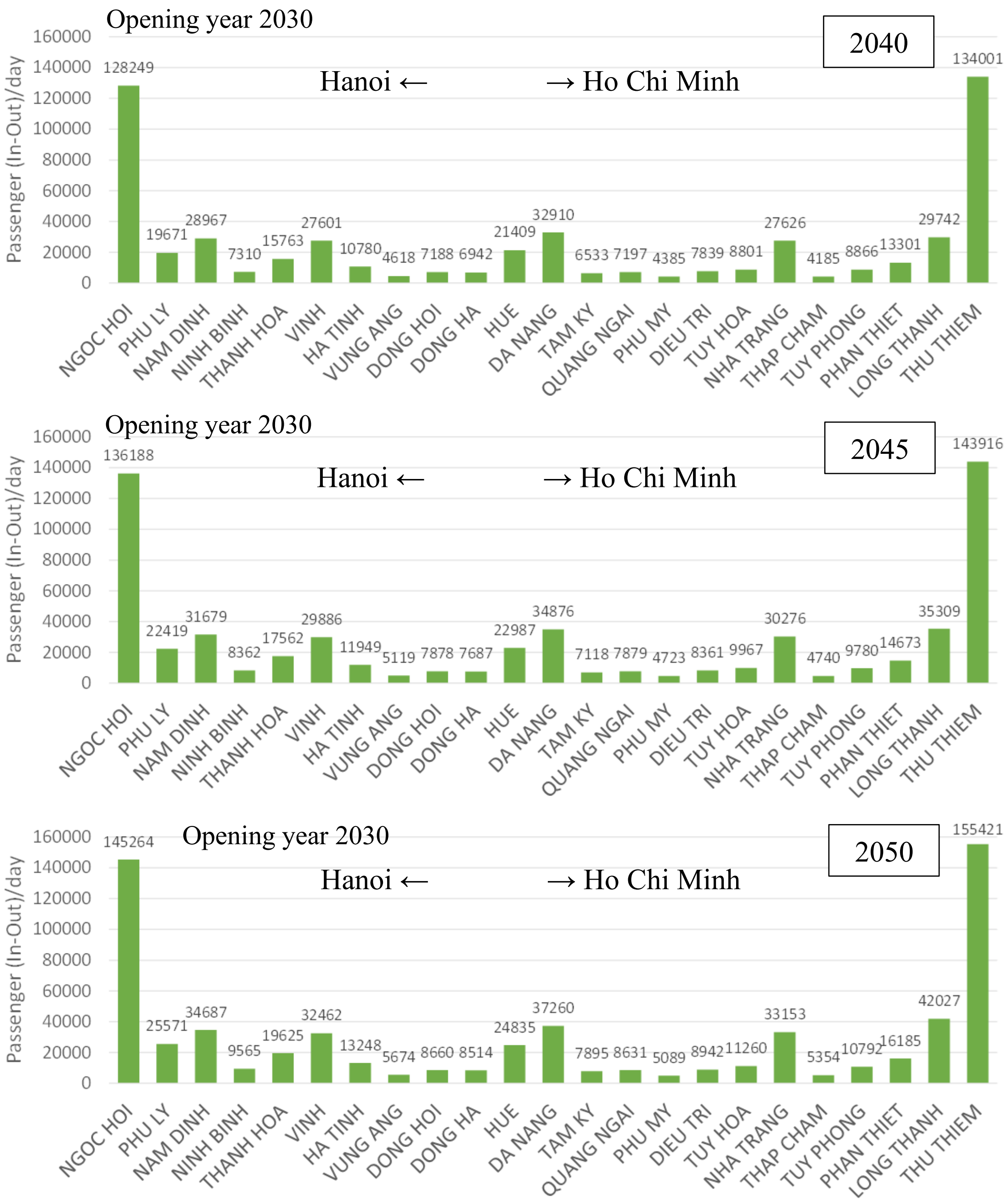
These passenger volumes at every station are estimated to approximately be increased by 50% in 5 years from the opening year.



Source: JICA Study Team

Figure 2.16: Number of Passenger at Every Proposed HSR Station (2030 and 2035)

In the full-scale development of HSR beyond 2040, Thu Thiem station in HCMC is utilized by the largest number of passengers as Long Thanh international airport will be operated by then.



Source: JICA Study Team

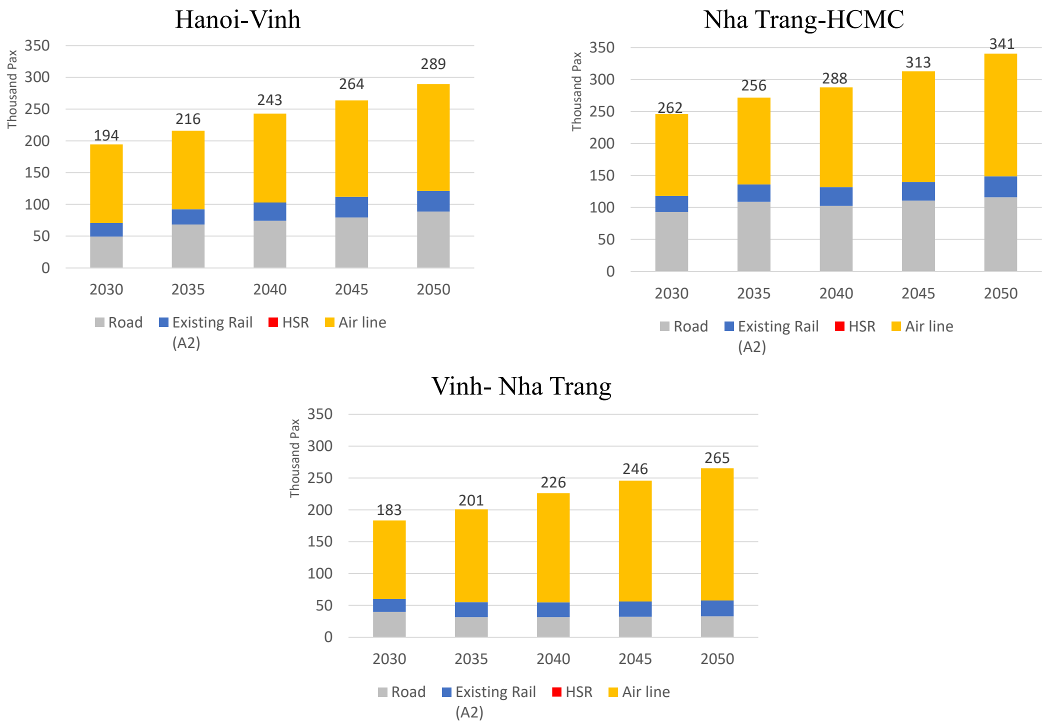
Figure 2.17: Number of Passenger at Every Proposed HSR Station (2040, 2045 and 2050)

2.2.7 Analysis and Evaluation of Forecasted Results

(1) Sectional Demand Transition and Modal Share Assessment

1) A2 Development without HSR (Scenario 1)

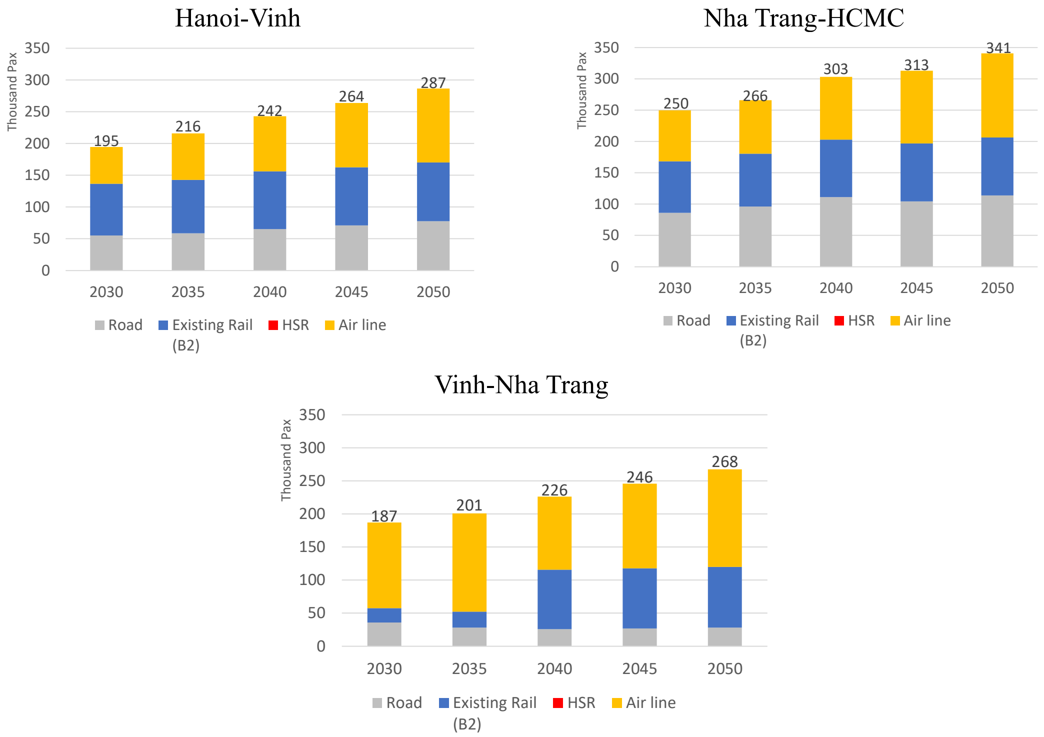
It is expected that passenger volume of section "Nha Trang – HCMC" is larger than other sections. The volume of the existing rail is limited due to its capacity issue.



Source: JICA Study Team

Figure 2.18: Modal Share and Transition of Three Sections for Scenario 1

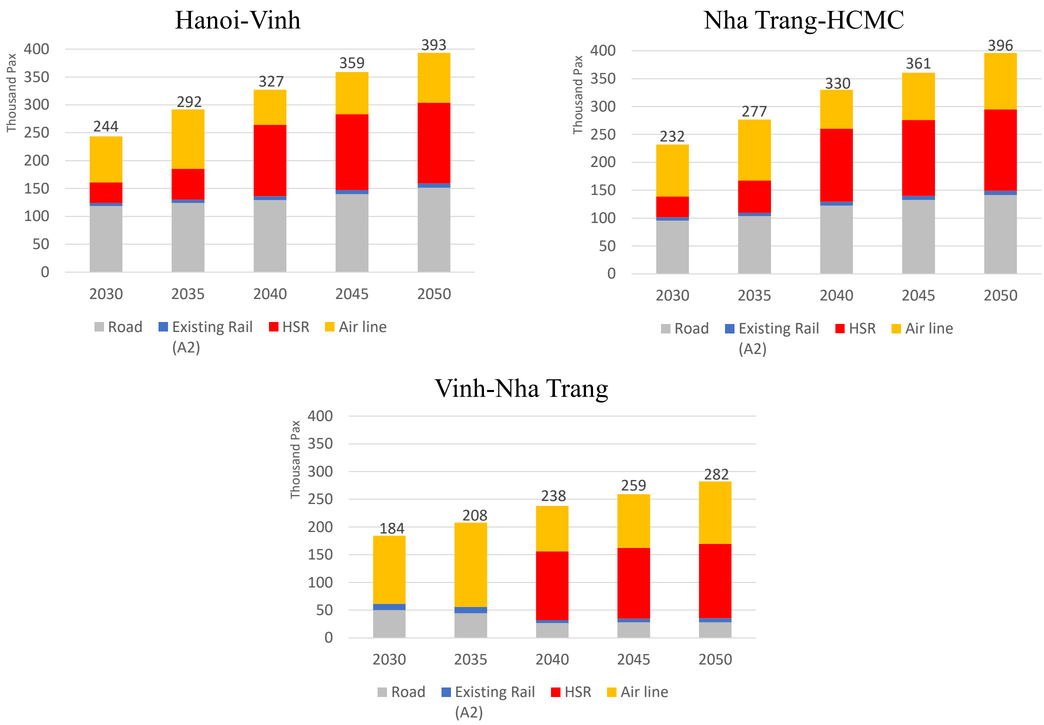
<u>2) B2 Development without HSR (Scenario 2)</u>



Source: JICA Study Team

Figure 2.19: Modal Share and Transition of Three Sections for Scenario 2

3) A2 Development with HSR (Scenario 3)

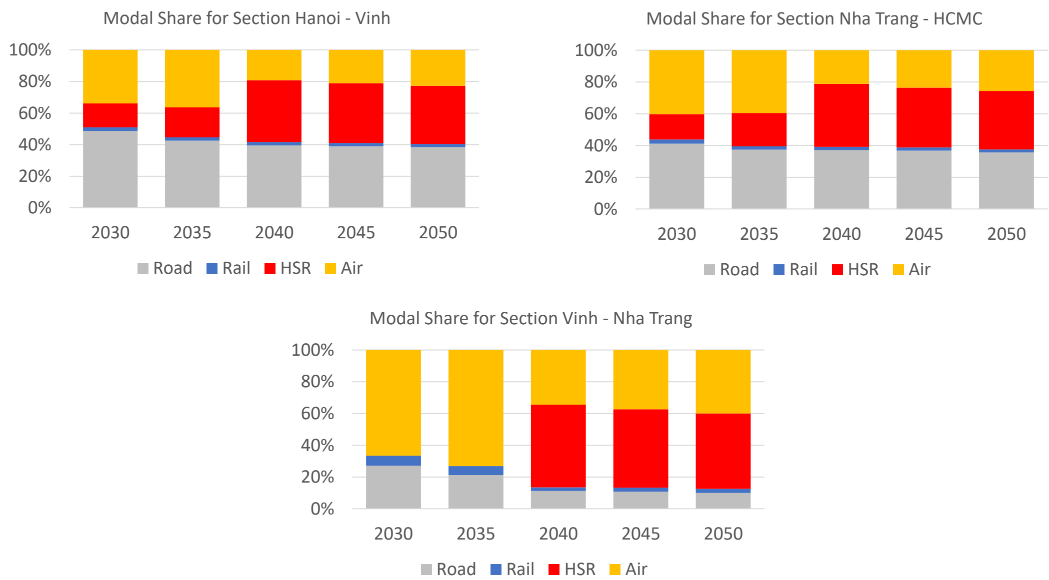


Source: JICA Study Team

Figure 2.20: Modal Share and Transition of Three Sections for Scenario 3

4) Modal share for A2 Development with HSR (Scenario 3)

Modal share of HSR for the period of tentative development before 2040 is around 15% for sections "Hanoi-Vinh" and "Nha Trang-HCMC," and the share after completion of the entire HSR is around 40% for all three sections.



Source: JICA Study Team

Figure 2.21: Modal Share for Scenario 3

(2) Capacity and Demand Gap Assessment for Every Transportation Modes

1) A2 Development without HSR (Scenario 1)

In Scenario 1, there are much insufficient capacity on transportation system in Vietnam, specifically on the existing railway and air infrastructure from early 2030s.

Table 2.17: Sectional Demand – Supply Assessment for Scenario 1

2030 A2				All section Hanoi - HCMC	Evaluation
Passenger	Road	NH, Expressway	Car	39,959	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	34,450	
	Rail	Existing Rail		11,528	
		HSR		0	
	Air			124,244	
	Total			210,182	
Transport Requirement	Road(pcu)	Passenger		16,689	
		Freight		61,161	
		Sub total		77,849	
	Existing Rail	Passenger		**20**	
		Freight		**36**	
		Sub total		56	
	HSR			-	
	Air			471	
Capacity	Road(pcu)	Minimum section		119,357	
	Existing Rail			50	
	HSR			0	
	Air			366 - 492	
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.65	OK
	Rail (Freight)	Capacity - Volume	Train/day	-6	Insufficient
	HSR	Capacity - Volume	Train/day	-	-
	Air	Capacity - Volume	Flight/day	-42	Insufficient

2035 A2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	31,900	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	30,380	
	Rail	Existing Rail		12,162	
		HSR		0	
	Air			145,911	
	Total			220,353	
Transport Requirement	Road(pcu)	Passenger		13,674	
		Freight		70,713	
		Sub total		84,387	
	Existing Rail	Passenger		**21**	
		Freight		**42**	
		Sub total		63	
	HSR			0	
	Air			553	
Capacity	Road(pcu)			119,357	
	Existing Rail			50	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.71	OK
	Rail	Capacity - Volume	Train/day	-13	Insufficient
	HSR	Capacity - Volume	Train/day	-	-
	Air	Capacity - Volume	Flight/day	-124	Insufficient

2040 A2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	33,560	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	31,853	
	Rail	Existing Rail		12,811	
		HSR		0	
	Air			169,739	
	Total			247,962	
Transport Requirement	Road(pcu)	Passenger		14,372	
		Freight		81,642	
		Sub total		96,014	
	Existing Rail	Passenger		**22**	
		Freight		**45**	
		Sub total		67	
	HSR			0	
	Air			643	
Capacity	Road(pcu)			161,500	
	Existing Rail			50	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.59	OK
	Rail	Capacity - Volume	Train/day	-17	Insufficient
	HSR	Capacity - Volume	Train/day	-	-
	Air	Capacity - Volume	Flight/day	-214	Insufficient

2045 A2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	35,212	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	33,440	
	Rail	Existing Rail		13,480	
		HSR		0	
	Air			187,429	
	Total			269,560	
Transport Requirement	Road(pcu)	Passenger		15,082	
		Freight		90,894	
		Sub total		105,976	
	Existing Rail	Passenger		**23**	
		Freight		**46**	
		Sub total		69	
	HSR			0	
	Air			710	
Capacity	Road(pcu)			177,893	
	Existing Rail			50	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.60	OK
	Rail	Capacity - Volume	Train/day	-19	Insufficient
	HSR	Capacity - Volume	Train/day	0	-
	Air	Capacity - Volume	Flight/day	-281	Insufficient

2050 A2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	37,245	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	36,216	
	Rail	Existing Rail		14,177	
		HSR		0	
	Air			204,797	
	Total			292,436	
Transport Requirement	Road(pcu)	Passenger		16,056	
		Freight		99,656	
		Sub total		115,712	
	Existing Rail	Passenger		**24**	
		Freight		**47**	
		Sub total		71	
	HSR			0	
	Air			776	
Capacity	Road(pcu)			177,893	
	Existing Rail			50	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.65	OK
	Rail	Capacity - Volume	Train/day	-21	Insufficient
	HSR	Capacity - Volume	Train/day	0	-
	Air	Capacity - Volume	Flight/day	-347	Insufficient

Source: JICA Study Team

2) B2 Development without HSR

Even if the improvement of the existing railway infrastructure as per the B2 development would proceed, there will be a capacity shortage of railway in 2030. In the years from 2030 to 2045, capacity shortage for railway infrastructure will be expanded year by year. It shows that additional railway tracks will be needed, specifically for passenger demand, to meet expanded demand in the future in spite of the improvement of the existing railway line. The HSR construction is a better solution to secure passenger capacity and development shall be started in the early 2030s.

Table 2.18: Sectional Demand – Supply Assessment for Scenario 2

2030 B2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	29,736	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	29,588	
	Rail	Existing Rail		103,213	
		HSR		0	
	Air			52,460	
	Total			214,997	
Transport Requirement	Road(pcu)	Passenger		12,901	
		Freight		76,451	
		Sub total		89,352	
	Existing Rail	Passenger		151	
		Freight		27	
		Sub total		178	
	HSR			-	
	Air			199	
Capacity	Road(pcu)			161,529	
	Existing Rail			170	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.55	OK
	Rail (Freight)	Capacity - Volume	Train/day	-8	Insufficient
	HSR	Capacity - Volume	Train/day	-	-
	Air	Capacity - Volume	Flight/day	230	OK

2035 B2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	24,718	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	24,060	
	Rail	Existing Rail		98,715	
		HSR		0	
	Air			72,851	
	Total			220,343	
Transport Requirement	Road(pcu)	Passenger		10,659	
		Freight		88,391	
		Sub total		99,050	
	Existing Rail	Passenger		144	
		Freight		32	
		Sub total		176	
	HSR			0	
	Air			276	
Capacity	Road(pcu)			161,529	
	Existing Rail			170	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.61	OK
	Rail	Capacity - Volume	Train/day	-6	Insufficient
	HSR	Capacity - Volume	Train/day	-	-
	Air	Capacity - Volume	Flight/day	153	OK

2040 B2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	27,130	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	26,323	
	Rail	Existing Rail		100,998	
		HSR		0	
	Air			93,505	
	Total			247,957	
Transport Requirement	Road(pcu)	Passenger		11,688	
		Freight		100,646	
		Sub total		112,335	
	Existing Rail	Passenger		147	
		Freight		36	
		Sub total		183	
	HSR			0	
	Air			355	
Capacity	Road(pcu)			204,329	
	Existing Rail			170	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.55	OK
	Rail	Capacity - Volume	Train/day	-13	Insufficient
	HSR	Capacity - Volume	Train/day	-	-
	Air	Capacity - Volume	Flight/day	74	OK

2045 B2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	29,220	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	28,343	
	Rail	Existing Rail		102,243	
		HSR		0	
	Air			109,746	
	Total			269,553	
Transport Requirement	Road(pcu)	Passenger		12,588	
		Freight		110,806	
		Sub total		123,393	
	Existing Rail	Passenger		149	
		Freight		39	
		Sub total		188	
	HSR			0	
	Air			416	
Capacity	Road(pcu)			204,329	
	Existing Rail			170	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.60	OK
	Rail	Capacity - Volume	Train/day	-18	Insufficient
	HSR	Capacity - Volume	Train/day	0	-
	Air	Capacity - Volume	Flight/day	13	OK

2050 B2				All section Hanoi - HCMC	
Passenger	Road	NH, Expressway	Car	31,659	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	30,696	
	Rail	Existing Rail		103,374	
		HSR		0	
	Air			127,436	
	Total			293,165	
Transport Requirement	Road(pcu)	Passenger		13,637	
		Freight		120,352	
		Sub total		133,988	
	Existing Rail	Passenger		151	
		Freight		42	
		Sub total		193	
	HSR			0	
	Air			483	
Capacity	Road(pcu)			204,329	
	Existing Rail			170	
	HSR			0	
	Air			366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.66	OK
	Rail	Capacity - Volume	Train/day	-23	Insufficient
	HSR	Capacity - Volume	Train/day	0	-
	Air	Capacity - Volume	Flight/day	-54	Insufficient

Source: JICA Study Team

3) A2 Development with HSR

As mentioned in the Scenario 2 for the existing railway in the previous section, additional track development, HSR, to increase rail capacity is necessary for the 2030s. It is, however, not realistic that the HSR will be in operation for all sections by 2040, since the project will require much time and cost due to the project scale. For time being, the only priority section in the North (Hanoi – Vinh) and South (Nha Trang – Ho Chi Minh) section which was recommended as priority sections in previous study, shall be operated by 2040 and full operation of HSR will be commenced since early 2040s. Insufficient capacity is expected for railway and air infrastructure in the 2030s, due to limited HSR development scenario, however, all transportation demand – capacity gap will be much improved beyond 2040, in which the HSR operation will be commenced. Even though the transportation demand for all modes will be improved, demand of the existing railway will be slightly over capacity in the 2040s as shown in below table. The capacity of the existing railway to be improved after 2040 is not so large. Therefore, the capacity shortage shall be covered by minor improvement on existing tracks, i.e. partial double tracks improvement at critical sections in the future.

Table 2.19: Sectional Demand – Supply Assessment for Scenario 3

2030				All section			
A2+HSR(NS)				Hanoi - Vinh	Vinh - Nha Trang	Nha Trang - HCMC	
Passenger	Road	NH, Expressway	Car	54,866	25,518	53,647	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	63,665	24,536	51,007	
	Rail	Existing Rail		5,680	11,471	5,980	
		HSR		37,346	0	38,098	
	Air			82,007	122,659	92,305	
	Total			243,564	184,184	241,037	
Transport Requirement	Road(pcu)	Passenger		24,910	10,967	22,985	
		Freight		90,020	50,617	54,914	
		Sub total		114,930	61,584	77,899	
	Existing Rail	Passenger		10	20	10	
		Freight		38	38	37	
		Sub total		48	58	47	
	HSR			51	0	52	
	Air			311	465	350	
Capacity	Road(pcu)			127,700	117,967	113,100	
	Existing Rail			50	50	50	
	HSR			300	0	300	
	Air			366 - 492	366 - 492	366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.90	0.52	0.69	OK
	Rail (Freight)	Capacity - Volume	Train/day	2	-8	3	Insufficient
	HSR	Capacity - Volume	Train/day	249	0	248	OK
	Air	Capacity - Volume	Flight/day	118	-36	79	Insufficient

2035				All section			
A2+HSR(NS)				Hanoi - Vinh	Vinh - Nha Trang	Nha Trang - HCMC	
Passenger	Road	NH, Expressway	Car	58,125	22,969	53,317	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	65,948	21,191	50,129	
	Rail	Existing Rail		5,984	11,624	5,684	
		HSR		57,061	0	57,239	
	Air			104,574	140,021	110,322	
	Total			291,693	195,806	276,691	
Transport Requirement	Road(pcu)	Passenger		26,206	9,762	22,775	
		Freight		100,217	58,515	66,676	
		Sub total		126,423	68,277	89,451	
	Existing Rail	Passenger		10	20	10	
		Freight		43	39	41	
		Sub total		53	59	51	
	HSR			78	0	78	
	Air			397	531	418	
Capacity	Road(pcu)			127,700	117,967	113,100	
	Existing Rail			50	50	50	
	HSR			300	0	300	
	Air			366 - 492	366 - 492	366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.99	0.58	0.79	OK
	Rail	Capacity - Volume	Train/day	-3	-9	-1	Insufficient
	HSR	Capacity - Volume	Train/day	222	0	222	OK
	Air	Capacity - Volume	Flight/day	32	-102	11	Insufficient

2040 A2+HSR(Full)				All section			
				Hanoi - Vinh	Vinh - Nha Trang	Nha Trang - HCMC	
Passenger	Road	NH, Expressway	Car	60,042	12,135	62,278	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	68,477	11,664	59,369	
	Rail	Existing Rail		7,007	5,496	7,007	
		HSR		130,049	128,831	134,801	
	Air			61,769	77,570	68,731	
	Total			327,344	235,696	332,187	
Transport Requirement	Road(pcu)	Passenger		27,114	5,215	26,702	
		Freight		122,370	66,640	75,293	
		Sub total		149,484	71,855	101,995	
	Existing Rail	Passenger		12	10	12	
		Freight		43	41	40	
		Sub total		55	51	52	
	HSR			107	106	111	
	Air			234	294	261	
Capacity	Road(pcu)			161,500	161,500	161,500	
	Existing Rail			50	50	50	
	HSR			300	300	300	
	Air			366 - 492	366 - 492	366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.93	0.44	0.63	OK
	Rail	Capacity - Volume	Train/day	-5	-1	-2	Insufficient
	HSR	Capacity - Volume	Train/day	193	194	189	OK
	Air	Capacity - Volume	Flight/day	195	135	168	OK

2045 A2+HSR(Full)				All section			
				Hanoi - Vinh	Vinh - Nha Trang	Nha Trang - HCMC	
Passenger	Road	NH, Expressway	Car	66,202	12,941	67,509	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	74,964	12,448	64,219	
	Rail	Existing Rail		7,481	6,456	7,181	
		HSR		130,049	128,831	141,275	
	Air			74,243	77,570	83,410	
	Total			352,940	238,246	363,594	
Transport Requirement	Road(pcu)	Passenger		29,830	5,562	28,928	
		Freight		140,102	73,378	83,734	
		Sub total		169,933	78,940	112,662	
	Existing Rail	Passenger		13	10	12	
		Freight		43	41	40	
		Sub total		56	51	52	
	HSR			112	109	116	
	Air			282	294	316	
Capacity	Road(pcu)			199,750	161,500	180,625	
	Existing Rail			50	50	50	
	HSR			300	300	300	
	Air			366 - 492	366 - 492	366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.85	0.49	0.62	OK
	Rail	Capacity - Volume	Train/day	-6	-1	-2	Insufficient
	HSR	Capacity - Volume	Train/day	188	191	184	OK
	Air	Capacity - Volume	Flight/day	147	135	113	OK

2050 A2+HSR(Full)				All section			
				Hanoi - Vinh	Vinh - Nha Trang	Nha Trang - HCMC	
Passenger	Road	NH, Expressway	Car	71,967	13,089	71,874	
		Coastal Rd. Hanoi-HCMC Rd.	Bus	80,990	12,614	68,265	
	Rail	Existing Rail		7,724	6,864	7,424	
		HSR		145,264	137,186	152,875	
	Air			87,696	109,114	99,688	
	Total			393,641	278,867	400,126	
Transport Requirement	Road(pcu)	Passenger		32,366	5,629	30,786	
		Freight		151,931	79,717	91,067	
		Sub total		184,298	85,346	121,852	
	Existing Rail	Passenger		13	12	13	
		Freight		44	42	40	
		Sub total		57	54	53	
	HSR			120	113	126	
	Air			333	414	378	
Capacity	Road(pcu)			199,750	161,500	180,625	
	Existing Rail			50	50	50	
	HSR			300	300	300	
	Air			366 - 492	366 - 492	366 - 492	**Evaluation**
Demand Supply Gap	Road(pcu)	Volume/Capacity Ratio	%	0.92	0.53	0.67	OK
	Rail	Capacity - Volume	Train/day	-7	-4	-3	Insufficient
	HSR	Capacity - Volume	Train/day	180	187	174	OK
	Air	Capacity - Volume	Flight/day	96	15	51	OK

Source: JICA Study Team

2.2.8 Conclusions and Recommendations (Two-step Case)

Capacity shortage on north-south corridor shall be found beyond 2030 even if existing rail infrastructure will be improved to double tracks (B2 level). This shortage will be expanded year by year specifically for rail and fright which shall cover long distance trips in whole Vietnam. In order to meet reasonable trip demand in Vietnam, appropriate transportation infrastructure for long trip passenger will be required in future and HSR is the better solution to cover such trip demand. However, even if HSR will be developed in couple with improvement for existing rail with A2 improvement plan (single track improvement), small lack of transportation capacity for existing rail infrastructure will be found. To cope with the issue, it is necessary for existing rail infrastructure to improve partial capacity enhancement which means section-wised double track improvement.

2.2.9 Alternative Case Results (Five-step Case)

An alternative HSR development case, Five-step Case, is considered due to the budget allocation issue in Vietnam. The passenger volume of HSR for the Five-step Case by target year, from 2030 to 2070, is summarized in the table below.

The characteristic of the passenger volume of HSR 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. Therefore, it may be reasonable to construct the HSR depending on the financial availability. However, a large scale social benefit cannot be expected until all sections from North to South, i.e. Hanoi – Ho Chi Minh, is connected.

Table 2.20: Passenger Volume of HSR for Five-step Case

Year	Section	Passenger Volume (Pax / day)
2030	Long Thanh – HCMC	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

3. Basic Design

3.1 Design Criteria

3.1.1 Design Speed

Design speed of each HSR in various countries is generally over 300 km/h as shown in Tables 1.6 - 1.9. The effect of speeding up is large for this route because the distance of the route is very long, at over 1,541 km. Therefore, for this route, a design speed that is in the fastest category in the world should be adopted. The design speed is set as shown in the following table.

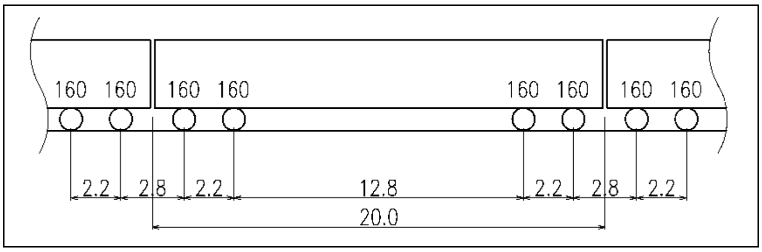
Table 3.1: Design Maximum Speed

Maximum Design Speed	Maximum Operation Speed
350 km/h	320 km/h

Source: JICA Study Team

3.1.2 Design Load

In consideration of the Japanese Shinkansen vehicle (E5 series), P-16 load is set as the design load.



Source: Standard of Railway Structure and Commentary (RTRI, 2012)

Figure 3.1: P-16 Load

3.1.3 Distance between Track Centers

The distance between track centers in this study is assumed at 4.3 m, which is the applied value for Tohoku Shinkansen. This value is the minimum value operated at a speed of 320 km/h. If the distance between track centers is small, the construction cost is reduced because the width of the structures such as bridges, embankments, and tunnels become small.

3.1.4 Maximum Cant

In a curved section, cant is needed for vehicles to avoid rolling over and for ride comfort not to deteriorate when passing the curve. Cant is set depending on gauge, curve radius, operation speed, etc. The maximum cant in this study is set at 180 mm according to the value of Tohoku Shinkansen that is actually operated at the maximum operation speed of 320 km/h. The allowable cant deficiency in this study is 60 mm, according to the value of Tohoku Shinkansen in Japan.

Table 3.2: Cant

Maximum Cant	Allowable Cant Deficiency
180 mm	60 mm

Source: JICA Study Team

3.1.5 Minimum Curve Radius

The minimum curve radius in this study is set at 6,000 m, in consideration of the design maximum speed and the maximum cant.

$$R = 11.8 \times V^2 / (Co + Cd) = 11.8 \times 350^2 / (180 + 61) \approx 6{,}000\ (m)$$[1]

Table 3.3: Curve Setting

Minimum curve radius	6,000 m
Design speed	350 km/h
Cant	180 mm

Source: JICA Study Team

3.1.6 Maximum Gradient

The basic maximum gradient in this study is set at 15‰, which is the basic maximum gradient for Shinkansen. However, the gradient is allowed up to 25‰, if it is inevitable by the impact to neighboring area .

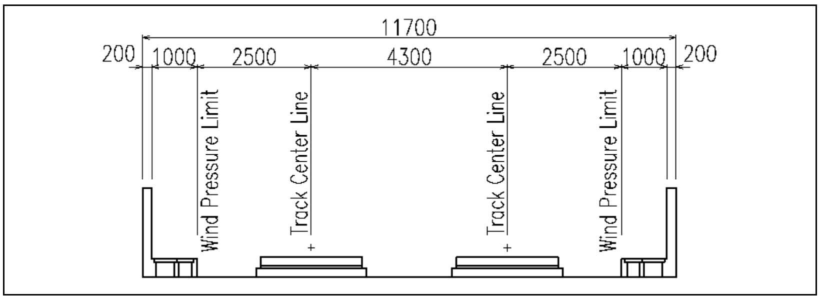
Table 3.4: Maximum Gradient

Basic maximum gradient	Inevitable gradient
15 ‰	25 ‰

Source: JICA Study Team

3.1.7 Formation Width

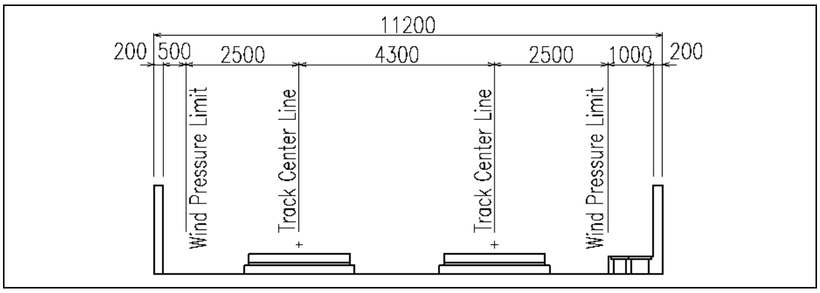
The formation width is set according to the distance between track centers, required width for track structures, maintenance aisle width (including wind pressure safety limit), cable installation width, and handrail width etc. A sample of formation width in case of a viaduct is shown in the following figures. Here, both plans are shown as whether the "Both side aisle" or "One side aisle" is applied is determined by the time of operation start.



Source: JICA Study Team

Figure 3.2: Formation Width of Viaduct (Both Side Aisle)

[1] The cant deficiency is 61 mm where minimum curve radius is 6,000 m at a design maximum speed of 350 km/h. However, since there are many cases where the maximum cant deficiency can be up to about 90 mm, the standard for the cant deficiency is set to 60 mm.



Source: JICA Study Team

Figure 3.3: Formation Width of Viaduct (One Side Aisle)

3.1.8 Track Structures

In the soil foundation where the deformation of the roadbed is expected, ballast track which can adjust the trajectory is assumed. For tunnels and viaducts sections where deformation is not expected, slab track that can reduce maintenance costs is assumed.

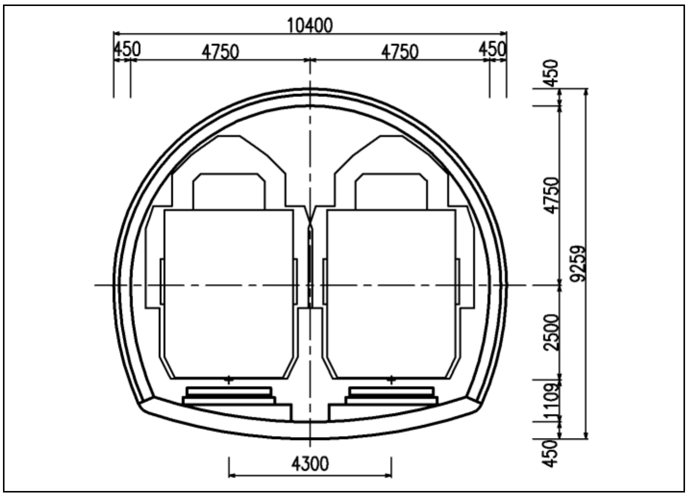
Table 3.5: Track Structures

Rail	60 kg/m
Turnout	#18
Scissors crossing	#16
Thickness of ballast	300 mm
Number of Sleepers	43 / 25 m

Source: Standard of Railway Structure and Commentary (RTRI, 2012)

3.1.9 Tunnel Shape

In general, the smaller tunnel area, the lower construction cost. Therefore, in this study, the tunnel shape is set according to achievements in Japan. The tunnel shape in this study is as follows. The lining thickness is an assumed value.



Source: JICA Study Team

Figure 3.4: Tunnel Shape

3.2 Route

3.2.1 Route between Stations

The HSR route is set based on the results of the F/S in 2009 and the previous study in 2013. With the change of the station site in this survey, the route between stations was also changed. The following matters (Table 3.6) were confirmed for the route plan by the local consultant. However, it is highly likely that the route plan will be reconsidered throughout the regional consultations.

Table 3.6: Matters for Confirmation Plane Routes between Stations

- Avoid tight and large buildings
- Avoid environmental protection area
- Avoid NATM tunnel under lakes (including dam lakes)
- Secure sufficient straight-line length at the station
- Secure a predetermined curve radius *Excluding unavoidable cases
- Cross angle at large river

Source: JICA Study Team

Table 3.7: Matters for Confirmation Longitudinal Routes between Stations

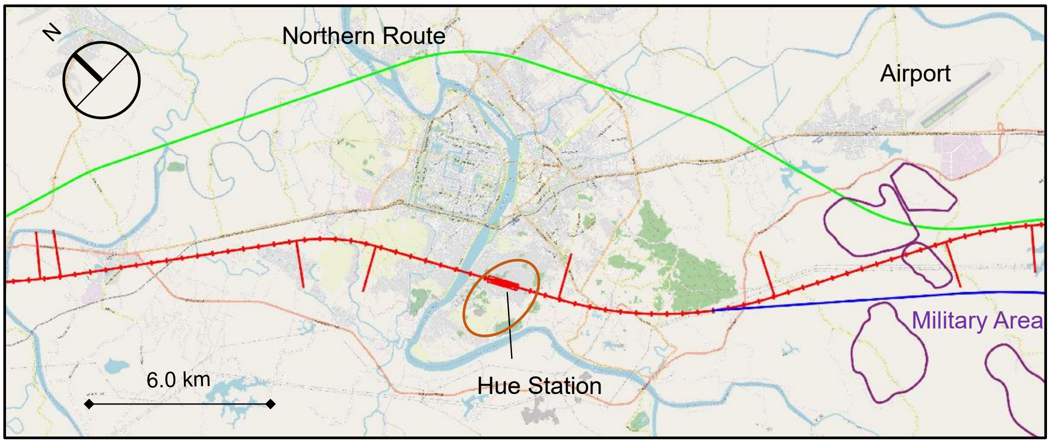
- Vertical curve should avoid transition curve
- If possible, vertical curve should avoid circular curve
- Girder height is necessary according to the girder length
  (L = 30 m : H = 2.4 m, L = 40 m : H = 2.6 m, L = 60 m : H = 3.8 m)
- At intersections, keep clearance (RL~GL)
  (RL~GL = Road (Railway) clearance height + Margin + Girder height + Track height)
- At valleys, keep enough clearance (RL~GL) for ground surface water flow
- In tunnel sections, avoid sag point because of drainages
- In tunnel sections, devise a gradient to avoid groundwater discharge
- Keep bridge pier height as low as possible around 20 m. In case the height is over 30 m, a detailed study is necessary
- In embankment sections, keep over 6 m embankment height at road crossings
- In embankment sections, keep less than 9 m embankment height

Source: JICA Study Team

3.2.2 Local Route Study

(1) Around Hue City

The route on the southern side of the city is the shortest, but it is highly likely that construction of stations and bridges would be restricted because of many remains and tombs (Brown circle). For the northern route, because the area is not developed, so there are less restrictions, but the total length becomes approximately 2.0 km longer and would interfere with the military areas. Therefore, it seems that the southern route (Redline → Blue line) is appropriate around Hue.

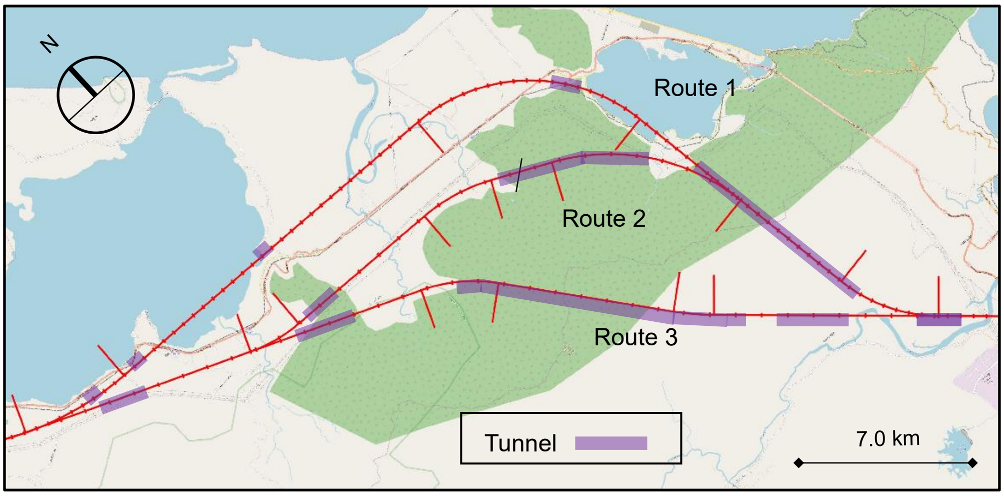


Source: JICA Study Team

Figure 3.5: Route Alternatives around Hue

(2) Hai Van Pass

In Hai Van Pass near Da Nang City, because the hilly land is approaching the coastline, tunnels are needed. The construction cost, construction period and surrounding structures of three route alternatives were compared in order to shorten the tunnels as well as the route itself.



Source: JICA Study Team

Figure 3.6: Route Alternatives around Hue

As a result, Route 2, which is moderate in terms of total length of the route and tunnel, seems appropriate for this area. In reference to the tunnel construction record in Vietnam (The longest of 6.28 km of "Hai Van road tunnel" is the longest), Route 3 which has the tunnel length of approximately 11 km was excluded.

Table 3.8: Comparison of Length around Hai Van Pass

Route	Total Route Length	Total Tunnel Length	Maximum Single Tunnel Length
1	47.0 km	13.4 km	6.9 km
2	44.2 km (-2.8 km)	20.5 km (+7.1 km)	7.3 km
3	40.6 km (-6.4 km)	21.3 km (+8.0 km)	10.9 km

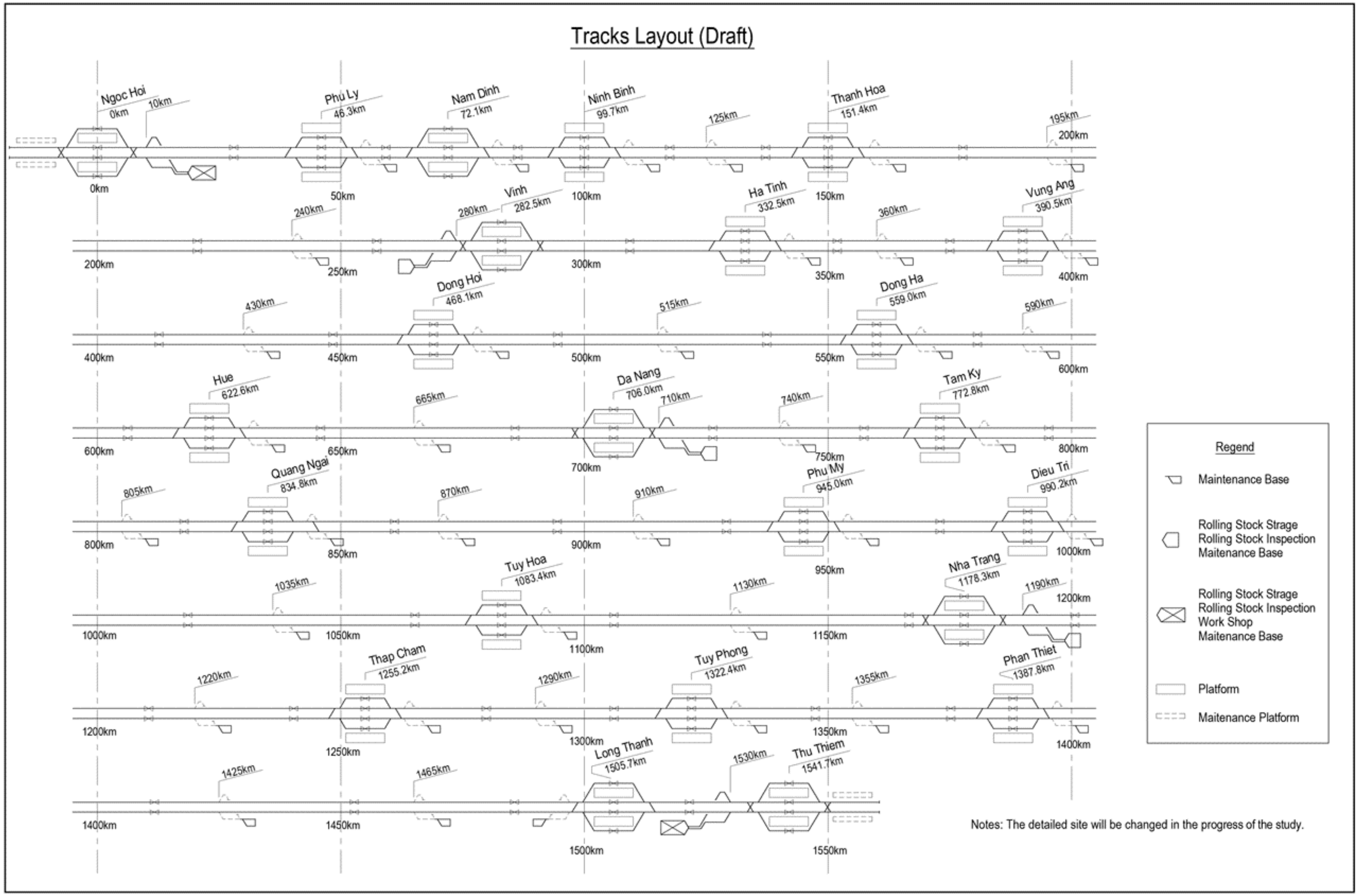
Source: JICA Study Team

3.2.3 Tracks Layout

The tracks layout is shown in Figure 3.7.

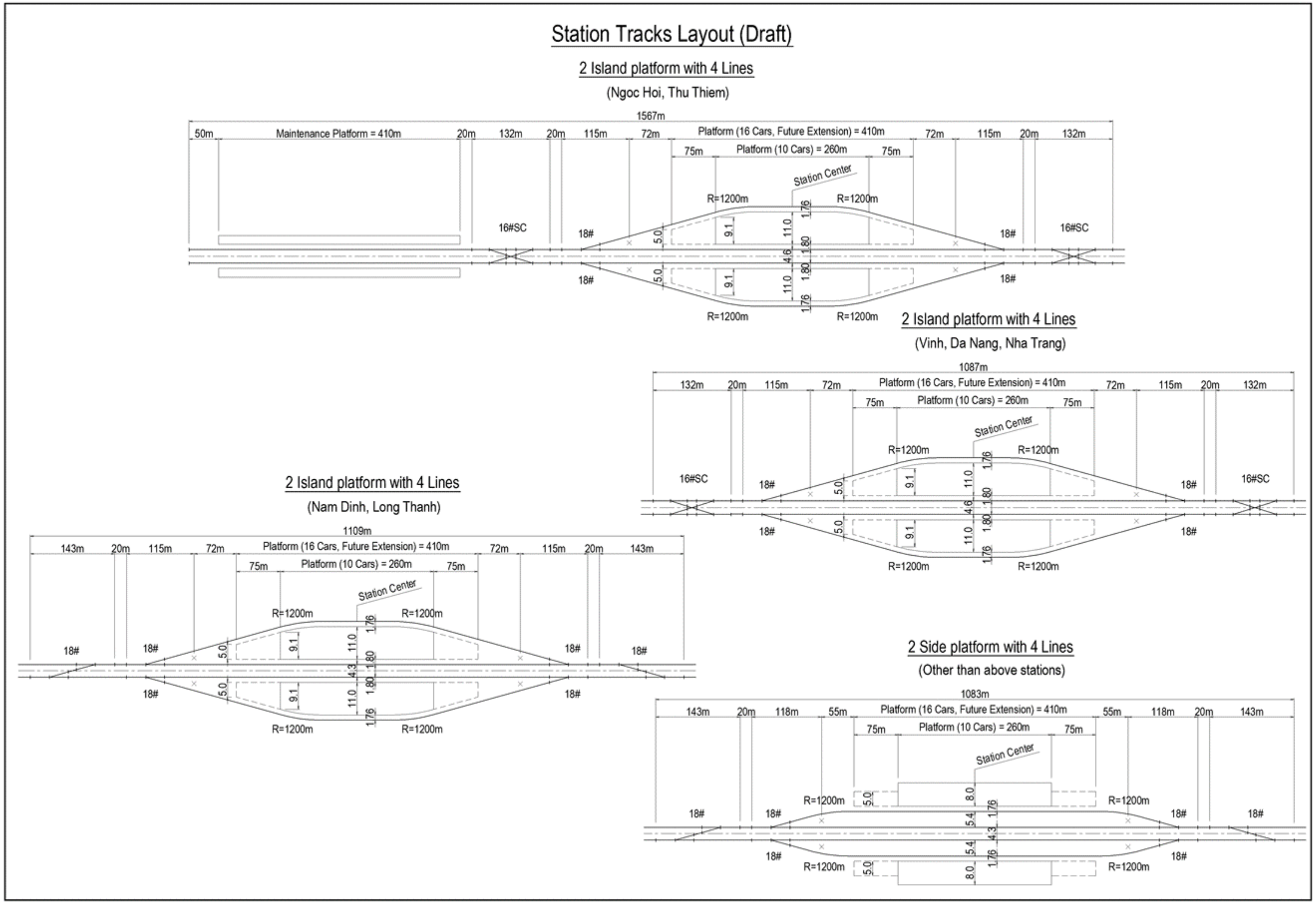
3.2.4 Station Tracks Layout

The station tracks layout is shown in Figure 3.8. There are two types of layout. One is “Two island platform with four lines” for express train stoppings. Another is "Two side platform with four lines" for other stations. For the terminal station (Ngoc Hoi, Thu Thiem), a maintenance platform for cleaning the vehicles inside shall be equipped.



Source: JICA Study Team

Figure 3.7: Track Layout



Source: JICA Study Team

Figure 3.8: Station Track Layout

3.3 Station Site Planning

3.3.1 Current Condition of Station Site

A total of 23 station sites have been selected under the Previous Study, and each proposed station site was physically analyzed for its city and urban development conditions, spatial relationship to the city center, bus terminals and railway station, technical issues, such as intersecting conditions with rivers, canals, roads, other infrastructures, and land uses.

(1) Station Site Selection Criteria

The following general criteria have been set for the station site analysis.

- There is a development potential for the target city and surrounding region as well as their economy through the development of an HSR station.
- There could be easy and effective transits and networking to be achieved among transportation systems of railways and road transports.
- There is no major discrepancy or conflict with the upper or superior national and regional development plans, and synergic development effect could be expected with these plans.
- The station site does not have major difficulty with land acquisition and resettlement.
- Standard station to station distance is considered as 50 km. Where station distance is greater than 50 km, track maintenance station should be located, if necessary.

(2) Existing Conditions of each Station Site and Surrounding Area

The general review after the site survey at each station site and surrounding area is summarized hereafter.

1. Station Name	**Ngoc Hoi**
Topography	Flatland
Land Category	Marshland and cultivated land
Distance (Existing Station)	Approx. 4 km (Van Dien Station)
Distance (Trunk Road)	Approx. 1 km (QL1A)
Population	7.588 Million (Hanoi)
Condition of existing railway station area	The station area is in a suburb of Hanoi and rather small with population and economic activities except its industrial establishment. Agricultural land spreads around the area.
Condition of HSR Station proposed area	The proposed site is located next to a small industrial zone and is in mainly agro land. There seems to have no major development issues except its distance to Hanoi city in order to link with surrounding regions.  There are several small scale industrial establishments within the farmland and wetland. Careful foundation design is required to suite such wetland conditions.

2. Station Name	**Phu Ly**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 4.5 km (from existing Phu Ly Station)
Distance (Trunk Road)	Approx. 1 km (QL21A)
Population	137,000
Condition of existing railway station area	Industrial Developments are taking place around the city. The station is in the heart of the town.
Condition of HSR Station proposed area	The proposed site is about 4.5 km away from the existing railway station and located in the rice field nearby national road 1A. There is no major issue for the station development, but careful analysis of soil bearing capacity is necessary as it is located among wetland along river.  Surrounding area of the station target site is gradually developing with houses, so that the land acquisition and resettlement may become larger.

3. Station Name	**Nam Dinh**
Topography	Flatland, River, Canal
Land Category	Cultivated land
Distance (Existing Station)	Approx. 4 km (from existing Nam Dinh station)
Distance (Trunk Road)	Approx. 1 km (from QL21A)
Population	380,000
Condition of existing railway station area	The station is located in the middle of the city where industrial parks are developing.
Condition of HSR Station proposed area	Proposed site is in the west side of the city, and is about 4 km from the existing railway station. The concern for the North Station option includes the new development around. The concern for the South Station option is more of the canal system right at the station, although it is located in the rice field with less acquisition issues.  The station site area is mainly farmland with some water channels, and the structural design should be carefully made with station arrangement among the channels.

4. Station Name	**Ninh Binh**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 6 km (from existing Ninh Binh station)
Distance (Trunk Road)	Approx. 2 km (from QL10)
Population	160,000
Condition of existing railway station area	The existing railway station is located on the edge of the city development, which is closer to a new development area with industry.
Condition of HSR Station proposed area	The proposed station site is in the rice field, and the area is in the urban development planned area in which new development is taking place. Physically, there are no serious issues for development.  The station target site is located at the southeast side of the existing railway station where new urban development is ongoing. Convenience will be increased while land issue could also become larger.

5. Station Name	**Thanh Hoa**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 1.7 km (from existing Thanh Hoa station)
Distance (Trunk Road)	Approx. 1 km (from QL45)
Population	435,000
Condition of existing railway station area	The existing station is located in the west side of the city, where urban and industrial developments are being conducted. The city has a good expansion form.
Condition of HSR Station proposed area	It is located in the agro land at about 1.7 km from the existing railway station. There are no major development issues.  There is not much technical problem at the station site as the surrounding area is farmland.

6. Station Name	**Vinh**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2.5 km (from Vinh station)
Distance (Trunk Road)	Approx. 1 km (from AH1)
Population	490,000
Condition of existing railway station area	The station is located on the west side of the city area, and is near the airport. Beach resort area is about 15 km away.
Condition of HSR Station proposed area	The site is proposed in the agro land west of the existing railway station (direct distance is about 2.5 km). As it is located in the flat land, there is no major issues except relocation of high voltage power line nearby. Besides, proper access road development is necessary for the HSR station.  There is not much technical problem at the station site except the high voltage power line for relocation.

7. Station Name	**Ha Tinh**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	N/A
Distance (Trunk Road)	Approx. 2 km (from QL1A)
Population	118,000
Condition of existing railway station area	Railway is running along a valley about 25 km west of the city, and there is no station. There are some historical elements, such as a small Fort, which could become tourism destinations.
Condition of HSR Station proposed area	Some parts of the HSR station is on the developed residential areas, and this could be an issue for land acquisition. Shifting the station site should be considered. Station development should include station front facility and service development, so that the affected land area may be larger, so more land acquisition issues might come into the project.  There is not much technical problem at the station site except the high voltage power line for relocation. However, larger developments are ongoing around the site, and these may cause issues of land acquisition.

8. Station Name	**Vung Ang**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	-
Distance (Trunk Road)	Approx. 1 km (from AH1)
Population	---
Condition of existing railway station area	There is no Railway Station nearby.
Condition of HSR Station proposed area	This station is located in the agro land near the major industrial and seaport developments. Industrial park-oriented transportation and its route should be a major concern. However, there seems no problem to develop HSR station.  There is not much technical problem at the station site as the surrounding land is for farming.

9. Station Name	**Dong Hoi**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 3 km (from existing Dong Hoi station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1A)
Population	160,000
Condition of existing railway station area	The existing station is in the center of the city and about 5 km away from the airport.
Condition of HSR Station proposed area	The HSR station is proposed in the agro land about 3 km south of the existing railway station. The development may not face much difficulties at this location. The city stretches northwest to southeast and some industrial developments are ongoing around.  There is not much technical problem at the station site along the national highway as the surrounding area is farmland.

10. Station Name	**Dong Ha**
Topography	Flat
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2 km (from existing Dong Ha station)
Distance (Trunk Road)	Approx. 1 km (from QL1A)
Population	82,000
Condition of existing railway station area	The existing station is located in the east of the city. The city is surrounded by rivers and lakes.
Condition of HSR Station proposed area	The proposed station site is in the rice field about 2 km east of the railway station between developed urban area and Thac Han River, and there doesn't seem to be any issue for the development.  There is not much technical problem at the station site as surrounding land is for farming.

11. Station Name	**Hue**
Topography	Undulated land
Land Category	Graveyard, Residential land
Distance (Existing Station)	Approx. 3 km (from existing Hue station)
Distance (Trunk Road)	Approx. 5 km (from QL49)
Population	354,000
Condition of existing railway station area	The existing railway station is located at the south bank of the river, where the city is developed in the historic castle (fortified) city structure.
Condition of HSR Station proposed area	Proposed HSR station is located at about 3 km west of the existing station, and the site is already developed as a residential area. Thus there is a land acquisition issue to raise. Since the station is planned as elevated structure, very long tall superstructure may disturb the landscape of historic city. The consideration of alignment change is important to move the station to the east side of the historic district and the river, where a new suburban development is planned, and development is ongoing.  The station site is located among gentle hilly land, where houses, small factories and graveyards are existing. These establishment may cause large land acquisition and resettlement issues.

12. Station Name	**Da Nang**
Topography	Undulated land
Land Category	Residential land
Distance (Existing Station)	Approx. 7 km (from existing Da Nang station)
Distance (Trunk Road)	Approx. 1 km (from QL1A)
Population	1.347 Million
Condition of existing railway station area	The railway station is located north of the airport and is projected for relocation to the west of the Da Nang Bay beach area.
Condition of HSR Station proposed area	Proposed station site is in the residential area west of the north beach, and some issues are concerned with the site, such as high voltage power line relocation and land acquisition.  The station site is overlapping with large residential areas with more land acquisition and resettlement issues. However, considering Da Nang's tourism-oriented industrial potentials, such investment may have more profitable effect to the city and region.

13. Station Name	**Tam Ky**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2 km (from existing Tam Ky station)
Distance (Trunk Road)	Approx. 1 km (from QL1A)
Population	81,000
Condition of existing railway station area	The existing station is located at the west edge of the urban area in the city. Buses operating along the national road also stops at the station area, although bus terminal is in the city area.
Condition of HSR Station proposed area	Proposed station site is mainly on the agro land. However, land acquisition is also necessary in the affected residential area. High voltage power line should be relocated.  There is a small power line for replacement. However, there is not much technical issues with the site.

xx. Station Name	**Dung Quat (for only future development assumed by the local consultants)**
Topography	Gentle valley of undulated land
Land Category	Forest and agricultural land
Distance (Existing Station)	Approx. 4 km (from existing Tri Binh station)
Distance (Trunk Road)	Approx. 3 km (from QL1A)
Population	---
Condition of existing railway station area	The railway station is located at the west of the industrial development around the seaport development zone. Existing railway station is located southwest of the industrial development area around San bay, and Chu Lai airport is also nearby about 5 km in distance.
Condition of HSR Station proposed area	It is located in the west of the industrial and seaport development about 13 km distance. Railway station is about 4 km away. It is located in the agro land, and there is no large issue for the development. The location is in a valley of undulated land so that the final layout should be carefully selected with consideration of alignment.  The station target site is located in the hilly area of farm and forest land. Such level change at the site should be carefully studied for final location selection.

14. Station Name	**Quang Ngai**
Topography	Undulated land, River
Land Category	Residential area
Distance (Existing Station)	Approx. 2 km (from existing Quang Ngai station)
Distance (Trunk Road)	Approx. 0.5 km (from DT623B)
Population	260,000
Condition of existing railway station area	The existing station is located at the west part of the city south of the river.
Condition of HSR Station proposed area	The proposed station site is about 2 km west of the railway station, and overwraps with residential area and river. Thus, land acquisition should be a major issue to this location.  The station site is located within the large residential area with more land acquisition and resettlement issues.

15. Station Name	**Phu My**
Topography	Flatland
Land Category	Cultivated and residential land
Distance (Existing Station)	Approx. 1 km (from existing Phu My station)
Distance (Trunk Road)	Approx. 1 km (from DT631B)
Population	---
Condition of existing railway station area	The existing station is located at the northwest of the town in a low-density area.
Condition of HSR Station proposed area	The proposed station site is about 1 km west of the railway station, where agricultural land occupies the most. However, some land acquisition against residential establishment is necessary.  There is not much technical problem at the station site as the surrounding area is farmland.

16. Station Name	**Dieu Tri (Qui Nhon)**
Topography	Flatland, River
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2 km (from existing Dieu Tri station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1A)
Population	656,000
Condition of existing railway station area	The existing station is located in the north of the city development. The city of Nhon Binh is located approximately 10 km to southeast of the station, and the industrial and port developments are ongoing nearby beach area.
Condition of HSR Station proposed area	The station site is proposed at about 2 km northeast of the railway station, and is a farmland without any development issues. However, the station front development may have some impact to the existing structures for relocation.  There is not much technical problem for development at the station site as the surrounding area is farmland.

17. Station Name	**Tuy Hoa**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 3 km (from existing Tuy Hoa station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1A)
Population	202,000
Condition of existing railway station area	The existing station is located in the residential area of the city north of Da Rang River.
Condition of HSR Station proposed area	The proposed station site is about 3 km south of the railway station, and west of the industrial development area stretches along the coastline. The airport is also near the HSR station site (10 km). The site is an agro land and has no major issue for the development.  There is not much technical problem at the station site as the surrounding area is farmland.

18. Station Name	**Nha Trang**
Topography	Flatland, River
Land Category	Cultivated and residential land (Road development overwraps)
Distance (Existing Station)	Approx. 4 km (from existing Nha Trang station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1C)
Population	421,000
Condition of existing railway station area	The existing station is located in the middle of the city along the government building district as the terminal station.
Condition of HSR Station proposed area	The proposed station site is about 4 km away from the railway station toward west, and is located in a low density residential area. Thus land acquisition is the main issue.  The station site is located in the area with some residential, factory establishment as well as city bypass so that the land acquisition and resettlement will be the large issues. However, considering Nha Trang's tourism-oriented industrial potentials, such investment may have a more profitable effect to the city and region.

19. Station Name	**Thap Cham**
Topography	Flatland
Land Category	Cultivated land, Residential land
Distance (Existing Station)	Approx. 1 km (from existing Thap Cham station)
Distance (Trunk Road)	Approx. 0.8 km (from QL27)
Population	161,000
Condition of existing railway station area	The existing station is at the west part of the city which is extended to the coast area. The region has a military airbase about 4 km to the north.
Condition of HSR Station proposed area	The proposed HSR station is about 1 km east of the existing railway station, and the site is in the rice field. Land acquisition should be necessary for the development.  The surrounding area is a low density residential area with farmlands; however, the land acquisition and resettlement will be the issues.

20. Station Name	**Tuy Phong**
Topography	Flatland
Land Category	Cultivated land, Residential land
Distance (Existing Station)	Approx. 12 km (from existing Song Mao station)
Distance (Trunk Road)	Approx. 0.1 km (from QL1A)
Population	91,000
Condition of existing railway station area	No station exists in the target area, as the railway alignment runs north of the area.
Condition of HSR Station proposed area	The proposed site is along the national road QL1A, where low-density development is identified. Some land acquisition is necessary for the development. (Railway station is about 12 km northwest from the HSR station site.)  The station target site is along the national highway with residential development at the north of the road. Some land acquisition and resettlement may cause issues.

21. Station Name	**Phan Thiet**
Topography	Flatland
Land Category	Cultivated land, Residential land
Distance (Existing Station)	Approx. 2 km (from existing Phan Thiet station)
Distance (Trunk Road)	Approx. 1.5 km (from QL1A)
Population	335,000
Condition of existing railway station area	Terminal station of national railway is located northwest of downtown area. The old station is abandoned.
Condition of HSR Station proposed area	The proposed station site is the northern part of the city. There are industrial and resort developments in the area, and the coastal resort development is growing. The site should be shifted about 500 m towards west to set the station with the existing railway station. (Railway station is about 9.5 km west of the HSR station site: Muong Man.) The proposed site is at the low-density residential area so that the resettlement and land acquisition should be issues for development.  The station site is located at the low-density residential area which is north of and near the existing railway station. Setting up these stations juxtaposing each other may have more positive impact to the city. However, land acquisition and resettlement will be issues.

22. Station Name	**Long Thanh**
Topography	Flatland
Land Category	Rubber tree plantation
Distance (Existing Station)	-
Distance (Trunk Road)	Approx. 3 km (from CT01)
Population	---
Condition of existing railway station area	No Station exists.
Condition of HSR Station proposed area	Future airport site among rubber plantation.  The station site is in the large rubber plantation zone with much less technical issues. The station development should take place with the airport development.

23. Station Name	**Thu Thiem (Ho Chi Minh)**
Topography	Flatland
Land Category	Redevelopment area
Distance (Existing Station)	-
Distance (Trunk Road)	-
Population	8.426 Million
Condition of existing railway station area	Saigon Station in the Ho Chi Minh city center is the core subject to link.
Condition of HSR Station proposed area	The proposed site is about 8 km east of Saigon Station, and located at the government-approved development land for station (which is currently an empty green area), and there would be no major development issues with the plan. If the alignment extends to Saigon Station, UG development should be considered because of high dense city development.  The proposed site has already been designated as the station development land by the government.

3.3.2 Recommendation to the Station Site Planning

(1) Current Development Activities

The following table describes current activities regarding the area around the target station sites.

Table 3.9: Current Activities around the Station Sites

	Station Name	**Additional Information**	**Remarks**
1	Ngoc Hoi (Hanoi)	There is a new concept considered by MOT 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, the passenger convenience will be drastically increased. However, the land acquisition is a major issue, and proposed solution is to set the HSR line with the Hanoi metro line No. 1. As if this plan could be selected, there would be large impacts to railway networks in Hanoi including metro line No. 1.	The described master plan is under development, and the complete information has not yet been open to public.
2	Vinh	The station site relocation is considered by the local government toward south from the current location.	Tourism resources in and around the city have development potentials.
3	Hue	The proposed station site is located near the historic city area. The local government has requested to study TOD with effective landscape preservation.	Current proposed site is located among large number of houses and others, and may cause large land acquisition and resettlement.

	Station Name	Additional Information	Remarks
4	Da Nang	The local government has the existing station relocation plan, which may come together with HSR station proposed site. The current proposed site is occupied by large number of illegal residents, so that the land acquisition could be a major issue as noted by some officials.	The relocation plan is shared by the local government.
5	Dung Quat	There are ongoing developments of trade port and industrial zones near the proposed station site, and there is a need to analyze the necessity of HSR station in this area.	
6	Nha Trang	Proposed station site is at the distance with the existing railway station of Nha Trang. The local government is studying the city west area development with HSR station, and a TOD study has been requested by the government.	There is a large potential with tourism development in the city.
7	Thu Thiem (Ho Chi Minh)	MOT and the local government are studying the possibility of extending the alignment to directly connect the HSR to Saigon station in the city center. Also, further extension of HSR to Can Tho is considered as a future development potential.	For the extension of HSR to Saigon Station, several routes are under the study.

Source: JICA Study Team

(2) Recommendation to the Station Site

According to the current activities around the target station sites, there might be some more cumbersome planning tasks and effort to be made before the finalization of the sites. The recommendation to the station site planning is summarized hereafter.

1) Ngoc Hoi

It is considered important to develop effective public transportation network, and HSR should be integrated in the network in order to improve and expand the industry and function of government administration in the capital of Hanoi. Ngoc Hoi station is in a long distance from the city center of Hanoi, so that shortening such physical distance is necessary with developing other transportation system connecting them. Earlier decision making is necessary for the future development of the HSR network integrated with the currently on-going development of Metro Line-1 project.

2) Ninh Binh

It is important to set the HSR development within the regional network development for not only the regional industrial areas but also tourism resources around the city, as there is a UNESCO registered natural resources at the west of the area. The city could expect visitor accesses from both north and south that the integration with the existing railway station is necessary.

3) Vinh

Vinh city has not only a tourism function but also connecting function 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 to the users. The city is expected for further economic development through the air service connection to the southern region.

4) Vung Ang

As the development of a trading port and industrial zones are expanding in the area, business person relating to manufacturing industry, factory operators, logistics services workers, etc. may be increasing in the future. Therefore, possible development of services in hotels, guest houses, entertainment, etc. could be considered together with the HSR station area development to support visitors and business persons to the port functions, industrial zones and logistics.

5) 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 large tourism industry-oriented region. Therefore, the city should have clear vision and role among the other tourist destinations, including Da Nang and Hoi An in order to enhance these developments together, instead of competing. The regional transportation network should be developed with the HSR system, to support such large tourism area.

6) Da Nang

The city of Da Nang is located along the coastal area in the center of the country with having the international airport in the middle of the city. Such merit of spatial order of the city should be further strengthened as the central gateway to the tourists with the HSR development connecting the tourism towards south and north from the city. Thus, strong networking with the existing railway station and the airport is mandatory with the HSR station development. There are other tourist destinations, such as Hue and Hoi An, as well as UNESCO heritage and natural resources. Da Nang should be the center of all these tourist destinations, and the HSR station could be the center of transportation network of these.

7) Phu My

There is an area which could be another tourism resource in the east of the HSR station site, and there is also unique natural salt farm industry. The area should be developed with diverse potentials of the industries, and the HSR development could become a trigger to such industrial development.

8) Dieu Tri

The developing industrial zones, seaport and tourist beaches in and around Qui Nhon east of Dieu Tri should be growing further, and the HSR development could support the growth. The alignment cannot run through the city of Qui Nhon, so that Dieu Tri station site should be well networked with urban transportation system, which may utilize the existing railway between Dieu Tri and Qui Nhon stations.

9) Nha Trang

The city of Nha Trang has a strong benefit with its 400 km plus distance from Ho Chi Minh city, and there are number of industrial and tourism developments ongoing along the coastline in between. The HSR development between Ho Chi Minh and Nha Trang is very important considering industry and business development in the southern region. The HSR development should take important role in order to draw more business and tourism opportunities to the region. Therefore, the transport integration at Nha Trang is the key to have such industrial development effect to the southern Vietnam region together with the transport network development in Ho Chi Minh City.

10) Tuy Phong

The station target area does not have large concentration of population or industrial development today. However, there are some development of renewable energy generation (wind power generation) and large scale thermal power plant along the coast. As the capacity of these power generation systems increases, industrial development may be expanded, and the demand of HSR might be increased as well in the future. The HSR station development should be carefully planned with long term regional development vision.

11) Thu Thiem

Ho Chi Minh city is the most populated industrial and business-oriented city in Vietnam. There are daily based traffic congestions taking place in many places in the city, and the urban public transportation system and network should be urgently enhanced to improve the situation. Among such development, the HSR development should also take major role in the city, and it is important to bring the HSR station at the closest location to the city center while the new airport development plan has been proposed. The HSR system needs to be integrated with the nationwide transportation system connecting major cities of the country. The currently proposed station site is located at about 7 km east of the city center and Saigon station, and this is one of the new urban development areas and expanding toward east today. Therefore, setting the station site at this location considering the east 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 development of international airport development. Thus, the HSR development would achieve an important role in the development of the southern region.

3.4 Regional Development Concept Plan along the HSR

The construction of the HSR is expected to contribute to the increase in people's movement between Vietnam's major cities such as Hanoi or Ho Chi Minh and another regional city, or between regional cities. In this section, the necessity of HSR from the perspective of regional development is described, and then, direction for industrial development in each regional city along the railway, achieved through making use of their respective industrial potential, is illustrated.

Meanwhile, in order to establish the HSR as a major public transportation for each city along the railway, it is necessary to take a measure which makes it easier for people to travel between railway stations and existing city centers. As the JICA Study Team recommends urban development structured based on a mass use of public transportation, direction for TOD (Transit-Oriented Development) in each city is explained as a measure to organize networks between areas around railway stations and existing city centers.

3.4.1 Necessity of HSR from the Perspective of Regional Development

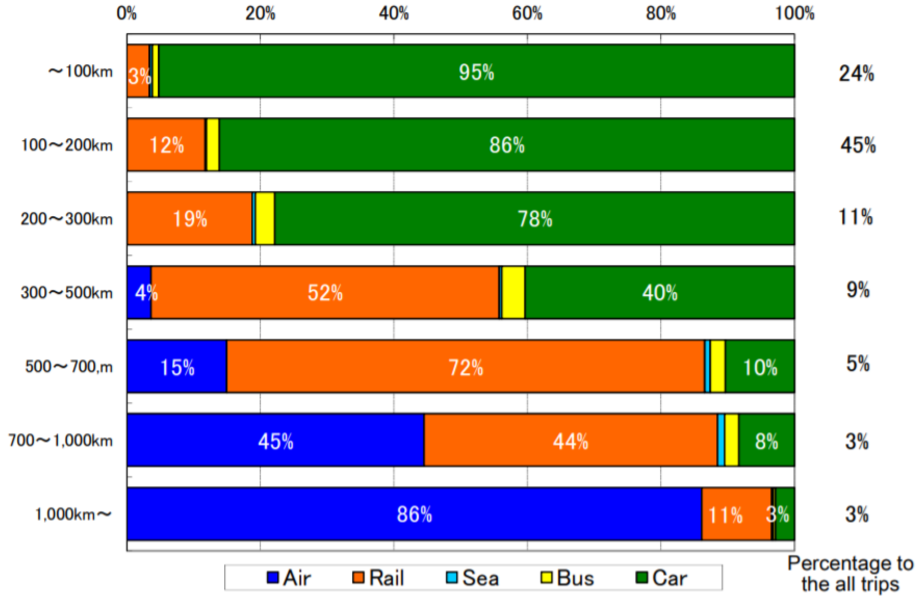
(1) Necessity of HSR from the Perspective of Industrial Development and Urban Development

In Vietnam, two of the country's major cities are Hanoi, located in the Northern area of the country, and Ho Chi Minh, located in the Southern area. As of 2016, the approximate population of these cities are as large as 7.32 million and 8.29 million[2], respectively. Currently, the economy in Vietnam is centered around these two major cities, which makes a bipolar situation.

The planned HSR between Hanoi and Ho Chi Minh is approximately 1,541 km in length. Except Hanoi and Ho Chi Minh, there is only one city along the railroad which has a population of over a million, which is called Da Nang. Da Nang is located about 700 km south from Hanoi and about 800 km north from Ho Chi Minh, and as of 2016, it has a population of approximately 1.34 million along the railway. In other cities along the railway, the population is smaller than a million.

[2] Statistic Data on Population and GDP of 63 provinces in Vietnam in 2016

According to the results of "Inter-regional Travel Survey" conducted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan[3], the distribution of transportation modes by distance shows that utilization rate of railway is highest for the travel of "300 km to 500 km" (52%) and of "500 km to 700 km" (72%) distance (see Figure 3.9). On the other hand, air flight (45%) is used more than railway (44%) for the travel of "700 km to 1,000 km" distance.



Source: Inter-regional Travel Survey" conducted by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT, 2010)

Figure 3.9: Distribution by Distance (Weekday)

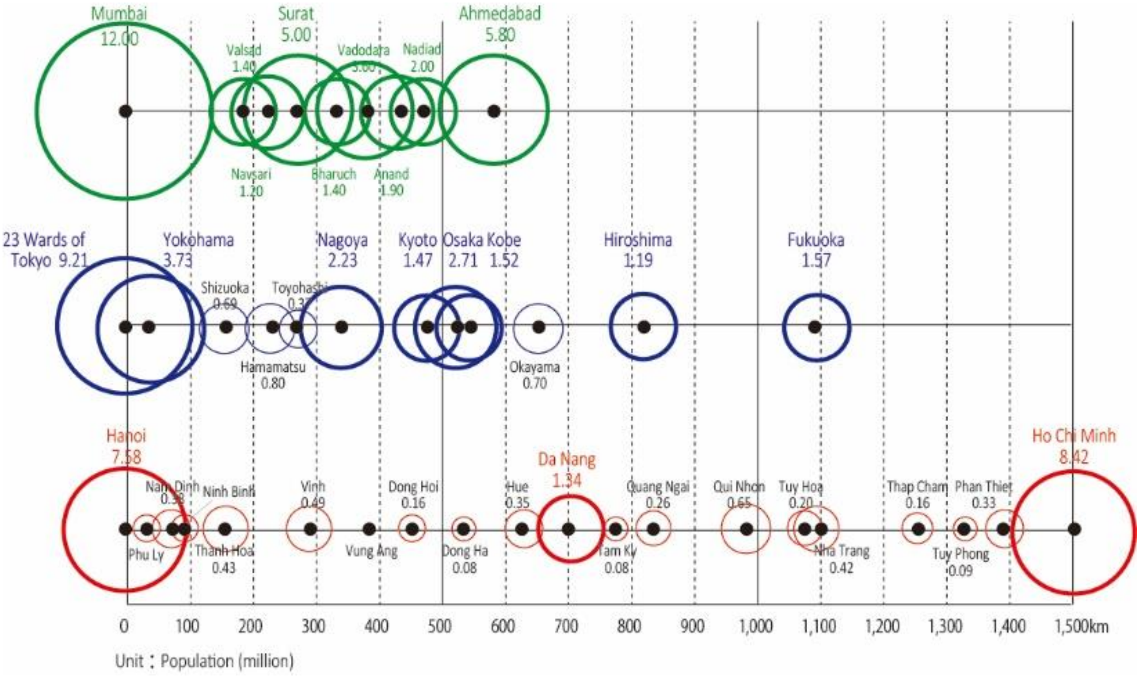
(2) Cities along HSR where Industrial Development should be Prioritized

For the promotion of the use of HSR, considering the above-mentioned, it is important to advance industrial development in the cities located 500 km to 700 km from major cities, to increase the urban population along the railroad and to create middle-sized urban areas there. In addition, industrial development in areas between a major city and a middle-sized city, or between two middle-sized cities, needs to be conducted in a step-by-step manner. The utilization of the HSR can be promoted when these middle-sized cities in regional areas are created and better connected.

Figure 3.10 shows the urban population along the HSR in India (between Mumbai and Ahmadabad), Japan (between Tokyo and Fukuoka) and Vietnam (between Hanoi and Ho Chi Minh). 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 city" in the country, following Hanoi and Ho Chi Minh.

Given the current urban population along HSR in Vietnam, Qui Nhon (population: approximately 650,000) and Nha Trang (population: approximately 650,000) follows Da Nang, as cities to be prioritized for industrial development. They are located about 500 km from Ho Chi Minh. Furthermore, it is desirable to develop industries in Vinh, which is located between Hanoi and Da Nang.

[3] "2010 Inter-Regional Travel Survey in Japan", the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)



Source: Urban population along HSR in India: Study report of Feasibility Study of High Speed Railway 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

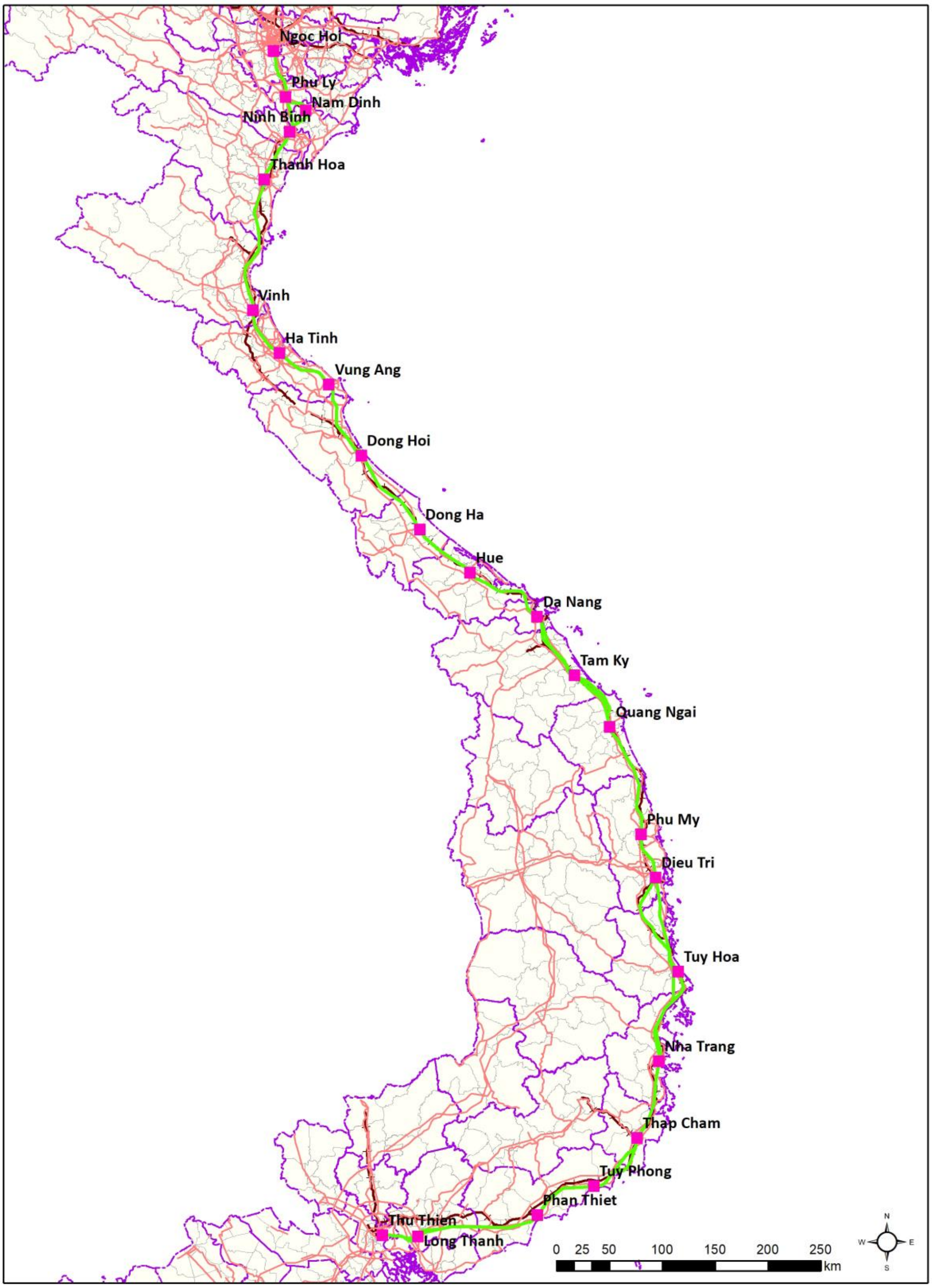
Figure 3.10: Comparison of Urban Population along High Speed Rail (India, Japan, Vietnam)

(3) Necessity of HSR from the Spatial Development

Since there have only been transport networks of main roads (highways) and normal railways in Vietnam until now, the development of HSR is expected to realize the establishment of high-speed transport network connections within the country. Provinces in Vietnam which benefit from this high-speed transport network are not limited to those located along the railway of HSR, but all the Provinces with a main road or a normal railway connecting to the HSR.

Figure 3.11 shows the layout of HSR and network of main roads[4] and normal railways connecting to the HSR. Table 3.10 shows the total area (km^2) of districts, which has a main road or railway connecting to the HSR in each Province, and its coverage rate compared to the whole area of each Province. According to Table 3.10, all 63 Provinces would benefit from the high-speed transport network developed through the construction of HSR. It is expected that, along with the HSR development and the resulting network encompassing a wider geographical area of the country, travel time between a major city such as Hanoi and Ho Chi Minh and a regional city, or between regional cities, is reduced. It is considered that the necessity of HSR is significant from the spatial development point of view.

[4] "main road" is defined as a wide-width road which has a traffic volume of more than 14,000 PCU/day (passenger car unit).



Note: Yellowish green lines indicates the layout of HSR. Red lines indicates the network of main roads or railways.
Source: JICA Study Team filling in the HSR route to the data provided by the local consultants

Figure 3.11: Transport Network of HSR, Main Roads and Railways

Table 3.10: Total Area (km²) of Districts which have a Main Road or Railway Connecting to the HSR in each Province and its Coverage Rate

Area	No	Name of Province	Administrative division	Terrain	Coverage Area*1 (km²)	Coverage Area Rate (%)
Northern Area	1	Hà Nội	City Central	Delta	3,458	100
	2	Vĩnh Phúc	Province	Delta	1,301	100
	3	Bắc Ninh	Province	Delta	607	74
	4	Quảng Ninh	Province	Delta	5,257	90
	5	Hải Dương	Province	Delta	1,369	82
	6	Hải Phòng	City Central	Delta	1,119	82
	7	Hưng Yên	Province	Delta	930	100
	8	Thái Bình	Province	Delta	1,596	100
	9	Hà Nam	Province	Delta	861	100
	10	Nam Định	Province	Delta	1,615	100
	11	Ninh Bình	Province	Delta	1,364	100
	12	Hà Giang	Province	Hilly or Mountain	6,741	85
	13	Cao Bằng	Province	Hilly or Mountain	5,891	88
	14	Bắc Kan	Province	Hilly or Mountain	3,937	81
	15	Tuyên Quang	Province	Hilly or Mountain	5,861	100
	16	Lào Cai	Province	Hilly or Mountain	6,116	96
	17	Yên Bái	Province	Hilly or Mountain	6,140	89
	18	Thái Nguyên	Province	Hilly or Mountain	3,521	100
	19	Lạng Sơn	Province	Hilly or Mountain	8,337	100
	20	Bắc Giang	Province	Hilly or Mountain	3,890	100
	21	Phú Thọ	Province	Hilly or Mountain	3,088	87
	22	Điện Biên Phủ	Province	Hilly or Mountain	5,821	61
	23	Lai Châu	Province	Hilly or Mountain	5,399	60
	24	Sơn La	Province	Hilly or Mountain	12,639	90
	25	Hòa Bình	Province	Hilly or Mountain	4,414	100
Middle Area	26	Thanh Hóa	Province	Coast	10,279	93
	27	Nghệ An	Province	Coast	16,514	100
	28	Hà Tĩnh	Province	Coast	5,962	100
	29	Quảng Bình	Province	Coast	7,966	100
	30	Quảng Trị	Province	Coast	4,613	100
	31	Thừa Thiên Huế	Province	Coast	4,668	97
	32	Đà Nẵng	City Central	Coast	885	90
	33	Quảng Nam	Province	Coast	8,328	79
	34	Quảng Ngãi	Province	Coast	3,025	59
	35	Bình Định	Province	Coast	5,338	88
	36	Phú Yên	Province	Coast	4,000	80
	37	Khánh Hòa	Province	Coast	3,109	67
	38	Ninh Thuận	Province	Coast	3,376	100
	39	Bình Thuận	Province	Coast	7,935	100
	40	Kon Tum	Province	Plateau	7,260	89
	41	Gia Lai	Province	Plateau	14,776	86
	42	Dak Lak	Province	Plateau	12,552	95
	43	Dak Nông	Province	Plateau	6,507	100
	44	Lâm Đồng	Province	Plateau	7,588	77

Area	No	Name of Province	Administrative division	Terrain	Coverage Area*1 (km²)	Coverage Area Rate (%)
Southern Area	45	Bình Phước	Province	Hilly or Flat	6,514	94
	46	Tây Ninh	Province	Hilly or Flat	2,502	62
	47	Bình Dương	Province	Hilly or Flat	2,684	100
	48	Đồng Nai	Province	Hilly or Flat	5,835	100
	49	Bà Rịa–Vũng Tàu	Province	Hilly or Flat	1,724	89
	50	Ho Chi Minh	City Central	Hilly or Flat	1,883	97
	51	Long An	Province	Delta	3,563	79
	52	Tiền Giang	Province	Delta	2,392	100
	53	Bến Tre	Province	Delta	1,934	85
	54	Trà Vinh	Province	Delta	2,207	100
	55	Vĩnh Long	Province	Delta	1,363	89
	56	Đồng Tháp	Province	Delta	2,800	83
	57	An Giang	Province	Delta	2,384	68
	58	Kiên Giang	Province	Delta	5,672	90
	59	Cần Thơ	City Central	Delta	1,439	100
	60	Hậu Giang	Province	Delta	1,503	93
	61	Sóc Trăng	Province	Delta	3,266	100
	62	Bạc Liêu	Province	Delta	2,460	100
	63	Cà Mau	Province	Delta	3,228	63

Note: The highlighted Provinces are the ones which the HSR passes through.
*1: "Coverage Area" means a sum of area of the entire district in which the transportation network (road, railway) is connected to HSR
Source: JICA Study Team

3.4.2 Potential for Industrial Development in Cities along HSR

In order to increase the use of the HSR, it is important to advance industrial development of cities along the railway during the railway construction. Based on the master plans of each local government, industries which can be promoted in each city along the railroad are shown in the boxes below.

It is expected that, along with the industrial development of these cities, the population (both residential and industrial) will increase. Currently, private means of transport such as automobiles or cars are preferred in Vietnam, and the existing urban areas tend to be congested. Through the construction of public transportation organically connecting regional traffic network with tourist destinations and other major facilities, it is foreseeable that people would be able to travel smoothly and traffic congestion would be alleviated. In the future, this also would lead to the enhancement of cities' values and attractiveness as well as to an increase in economic impact.

To encourage the shift from private to public transport, it is necessary to improve regional transport networks, including the development of HSR. For the central section of the whole railway (between Vinh station and Nha Trang station), which is the target area of this survey, the concept of Transit Oriented Development (hereinafter referred to as "TOD") for each station which can be driven by the construction of HSR is described.

The northern part (between Ngoc Hoi station and Vinh station) and the southern part (between Nha Trang station and Thu Thiem station) are beyond the scope of this section as they are already compiled in the Previous Study. Also, in particular, the concept plan of TOD for five stations which have a large urban population along the railway (Vinh, Hue, Da Nang, Dieu Tri and Nha Trang) are elaborated in the next sub-section.

1. Station Name	**Ngoc Hoi**
Topography	Flatland
Land Category	Marshland and cultivated land
Distance (Existing Station)	Approx. 4 km (Van Dien Station)
Distance (Trunk Road)	Approx. 1 km (QL1A)
Population	7.588 Million (Hanoi)
Industrial development potential	Industrial and administrative functions are concentrated in the capital city of Hanoi. The target area is expected to develop by playing a role as an undertaker of expanded and enhanced these functions of Hanoi.

2. Station Name	**Phu Ly**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 4.5 km (from existing Phu Ly Station)
Distance (Trunk Road)	Approx. 1 km (QL21A)
Population	137,000
Industrial development potential	Mineral resources such as lime, plaster and stones are abundant, and the expansion of manufacturing sector such as cement production business can be expected. Also, there is a potential for the development of metal processing and electronic industry.

3. Station Name	**Nam Dinh**
Topography	Flatland, River, Canal
Land Category	Cultivated land
Distance (Existing Station)	Approx. 4 km (from existing Nam Dinh station)
Distance (Trunk Road)	Approx. 1 km (from QL21A)
Population	380,000
Industrial development potential	The strengthening of textile industry and the promotion of professional training services to deal with the increased size of the textile industry are expected.

4. Station Name	**Ninh Binh**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 6 km (from existing Ninh Binh station)
Distance (Trunk Road)	Approx. 2 km (from QL10)
Population	160,000
Industrial development potential	The target city it the place once flourished with manufacturing business. Further development of industry sector, processing of construction materials and food processing, in particular, is expected. Also, there is a potential in tourism since in the Western part of the target city lies natural tourism resources registered as the world heritage by UNESCO.

5. Station Name	**Thanh Hoa**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 1.7 km (from existing Thanh Hoa station)
Distance (Trunk Road)	Approx. 1 km (from QL45)
Population	435,000
Industrial development potential	The target city not only retains a great number of historical sites but also holds industries remaining for a long period of time. It could be possible for both industry and tourism business to be activated. In addition, beach areas near the target city may have a potential as a newly developed tourist destination.

6. Station Name	**Vinh**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2.5 km (from existing Vinh station)
Distance (Trunk Road)	Approx. 1 km (from AH1)
Population	490,000
Industrial development potential	In the target city, some part of its coastal area and historical sites in urban areas already constitute tourist attractions. There is a fair potential for the expansion of tourism and its related industries.
TOD (Transit Oriented Development) policy	It is shown in the next paragraph.

7. Station Name	**Ha Tinh**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	N/A
Distance (Trunk Road)	Approx. 2 km (from QL1A)
Population	118,000
Industrial development potential	In the Northern or Eastern part of the target city, tourism development through marine eco-tourism may be possible. As universities and industrial parks are located in the Southern part, it is expected that industrial clusters composed of information technology services (software development and IT customer services, etc.) would be established.
TOD (Transit Oriented Development)	Currently, bus is the only means for public transportation in the city. Considering TOD of the existing urban areas, it is necessary to connect the railway station of HSR with the existing bus terminal in the city. In addition, there is an ongoing development of industrial park in the eastern coastal area of the target city. Through the formation of a transport network, which strengthens the connection between HSR station and industrial parks, the improvement of public transportation network in the backland of development site of industrial parks. Along with this improvement, the effect of regional development is expected to be produced.

8. Station Name	**Vung Ang**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	-
Distance (Trunk Road)	Approx. 1 km (from AH1)
Population	---
Industrial development potential	Metal and metallurgy industry and industries related to port development are expected to be fostered and strengthened, together with other labor-intensive or export-oriented industries. In the coastal area of the target site, some projects, such as port construction for trade promotion or industrial park development, are underway.
TOD (Transit Oriented Development)	As the target area has been focused on the development of industries related to trade and port, a future public transport network needs to link these newly developed sites with the HSR station. Through this linkage, it may be possible for a new business related to trade to be created. In addition, it is expected that lifestyle service industry will grow, thanks to the port development ongoing in the eastern coast and the accompanying increase of regional population. Development of transport network linking HSR railway with port area or industrial parks will be able to handle the region's traffic demand. At the same time, the development effect which can drive manufacturing businesses, in general, is expected to be produced.

9. Station Name	**Dong Hoi**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 3 km (from existing Dong Hoi station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1A)
Population	160,000
Industrial development potential	The target city is famous among tourists for its archeological sites and nature, and the further development of tourism is expected. Additionally, there is a potential in the growth of service industry for archeology researchers as well as for tourist.
TOD (Transit Oriented Development)	The city has tourist destinations such as a unique cave registered as the world heritage by UNESCO and other natural resources. Also, there is an ongoing beach resort development along the coast. It is plausible that the effective formation of traffic network connecting HSR railway, urban center and these tourist resources leads to the expansion of tourism-related industries.

10. Station Name	**Dong Ha**
Topography	Flat
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2 km (from existing Dong Ha station)
Distance (Trunk Road)	Approx. 1 km (from QL1A)
Population	82,000
Industrial development potential	The city aims to integrally develop manufacturing and construction industry, services and trade industry and agriculture, forestry and fisheries industry, in order to advance its economic restructuring.
TOD (Transit Oriented Development)	For the enhancement of potential for industrial development in each sector, the HSR station is connected to the major facilities within the target city. Although the city does not currently have a large, core industry, it is located in the middle of neighboring tourist destinations, including Hue city. Therefore, along with the tourism development in Hue city, the target city of Dong Ha may probably play a role in the related services industry. Through the establishment of public transport network linking HSR station with urban areas, the indirect effect for region-wide tourism development may be possible.

11. Station Name	**Hue**
Topography	Undulated land
Land Category	Graveyard, Residential land
Distance (Existing Station)	Approx. 3 km (from existing Hue station)
Distance (Trunk Road)	Approx. 5 km (from QL49)
Population	354,000
Industrial development potential	The target city is one of the famous destinations of historical sightseeing in Vietnam. Further growth of tourism industry and development of tourism-related service businesses can be expected.
TOD (Transit Oriented Development)	It is shown in the next paragraph.

12. Station Name	Da Nang
Topography	Undulated land
Land Category	Residential land
Distance (Existing Station)	Approx. 7 km (from existing Da Nang station)
Distance (Trunk Road)	Approx. 1 km (from QL1A)
Population	1.347 Million
Industrial development potential	The target city is one of the famous destinations for beach resort tourism in Vietnam. Further growth of tourism industry and development of tourism-related service businesses can be expected.
TOD (Transit Oriented Development)	It is shown in the next paragraph.

13. Station Name	Tam Ky
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2 km (from existing Tam Ky station)
Distance (Trunk Road)	Approx. 1 km (from QL1A)
Population	81,000
Industrial development potential	The target city lies on the same straight line connecting sightseeing sites of Da Nang and Hoi An, and thus has a potential for the development of tourism-related service industry. The target city of Tam Ky could play a role as a supplementary to the expanded tourism industry of these bigger cities of Da Nang and Hoi An, and thereby the regional development may be made possible.
TOD (Transit Oriented Development)	The HSR station is linked with the existing urban center, and at the same time, the public transport network within the urban center is further improved. Although the city does not have a large, core industry, it is located near surrounding tourism destinations including ones in Da Nang and Hoi An. Therefore, it may be possible that the city of Tam Ky plays a role in the tourism-related services industry. Through the establishment of public transport network linking HSR station with urban areas, the indirect effect for region-wide tourism development may be probable.

xx. Station Name	Dung Quat (for only future development assumed by local consultants)
Topography	Gentle valley of undulated land
Land Category	Forest and agricultural land
Distance (Existing Station)	Approx. 4 km (from existing Tri Binh station)
Distance (Trunk Road)	Approx. 3 km (from QL1A)
Population	---
Industrial development potential	Trading port and industrial zone are planned to be constructed in the areas around the coast. There is a potential in the development of service businesses and logistics businesses related to these construction projects.
TOD (Transit Oriented Development)	The TOD takes into account the connectivity of the HSR station, industrial zone, seaport and airport. The airport in the northern part of the city and industrial park development in its surrounding places are the priority areas for the city's fostering of industry. The formation of an urban transport network encompassing all these places would contribute to the enhancement of regional industrial development.

14. Station Name	**Quang Ngai**
Topography	Undulated land, River
Land Category	Residential area
Distance (Existing Station)	Approx. 2 km (from existing Quang Ngai station)
Distance (Trunk Road)	Approx. 0.5 km (from DT623B)
Population	260,000
Industrial development potential	In the city, there are several small-scale industrial facilities. The city specifically focuses on the strengthening of manufacturing and construction industry, but development is aimed to be expanded in other areas as well; including oil refinery, constriction material, ceramics, glass manufacturing, metallic processing, shipbuilding and electronics. In addition, growth of mineral resource development including iron, tin and rare earth can be expected. Meanwhile, resort development projects are planned in five major places, and the tourism industry is expected to be developed further.
TOD (Transit Oriented Development)	The HSR station is connected to the existing urban areas, and at the same time, the existing public transport network within urban areas is upgraded. The airport in the northern part of the city and industrial park development in its surrounding places are the priority areas for the city's industrial development. The formation of an urban transport network encompassing all these places would contribute to the enhancement of regional industrial development.

15. Station Name	**Phu My**
Topography	Flatland
Land Category	Cultivated and residential land
Distance (Existing Station)	Approx. 1 km (from existing Phu My station)
Distance (Trunk Road)	Approx. 1 km (from DT631B)
Population	---
Industrial development potential	In the eastern coastal part of the city, expansion of salt farm and its related industries are expected to be promoted.
TOD (Transit Oriented Development)	The HSR station is connected to the existing urban areas, and at the same time, the existing public transport network within urban areas is upgraded. As the target city has a low population density and densely populated areas are hardly observed, basic traffic network linking major place in the city would contribute to the activation of local economy.

16. Station Name	**Dieu Tri (Qui Nhon)**
Topography	Flatland, River
Land Category	Cultivated land
Distance (Existing Station)	Approx. 2 km (from existing Dieu Tri station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1A)
Population	656,000
Industrial development potential	The target city is adjacent to the city of Qui Nhon, a large-scale industrial city which has a significant number of population. There has been an ongoing development of the beach area located in the southern part of the city. In the industrial zones where multi-sector businesses are situated, larger sized industry development such as port construction might possibly to be implemented in the future. The expansion of trade / export-related industry is also expected.
TOD (Transit Oriented Development)	It is shown in the next paragraph.

17. Station Name	**Tuy Hoa**
Topography	Flatland
Land Category	Cultivated land
Distance (Existing Station)	Approx. 3 km (from existing Tuy Hoa station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1A)
Population	202,000
Industrial development potential	Science and technology is positioned as one of the major driving forces towards the target city's socio-economic development. In the target city, strengthening of high-tech industry and other high value-added industries can be expected.
TOD (Transit Oriented Development)	As urban areas and development sites geographically spread through coastal areas in the target city, it is necessary to connect all these sites through public transport network. This connecting network needs to include the existing railway station, HSR station and airport. In the target city, industrial development is centered around the establishment of industrial parks in coastal areas in the east part of the city. Building of a transport network linking industrial zones including the railway station with residential zones would lead to regional industrial network.

18. Station Name	**Nha Trang**
Topography	Flatland, River
Land Category	Cultivated and residential land (Road development overwraps)
Distance (Existing Station)	Approx. 4 km (from existing Nha Trang station)
Distance (Trunk Road)	Approx. 0.5 km (from QL1C)
Population	421,000
Industrial development potential	The target city is one of the several places in Vietnam which attract many tourists by city sightseeing and beach sightseeing. Further expansion of tourism industry and development of tourism-related service industry are expected.
TOD (Transit Oriented Development)	It is shown in the next paragraph.

19. Station Name	**Thap Cham**
Topography	Flatland
Land Category	Cultivated land, Residential land
Distance (Existing Station)	Approx. 1 km (from existing Thap Cham station)
Distance (Trunk Road)	Approx. 0.8 km (from QL27)
Population	161,000
Industrial development potential	As Ninh Thuan province, in which the target city of Thap Cham is located, six major sectors (energy, tourism, agriculture, forestry, fishery, processing) are planned to be promoted. In particular, development of an industrial cluster is designated as one of the targets of development; the related industries are expected to be fostered. It is desirable to effectively demarcate industries in the target city from the ones in Ho Chi Minh city.

20. Station Name	Tuy Phong
Topography	Flatland
Land Category	Cultivated land, Residential land
Distance (Existing Station)	Approx. 12 km (from existing Song Mao station)
Distance (Trunk Road)	Approx. 0.1 km (from QL1A)
Population	91,000
Industrial development potential	There is a large-scale power plant in the eastern part of the target city. If the development of energy sector is realized, development of service business related to energy sector such as professional training and attraction of industry which require a large volume of power may be made possible. It is desirable to effectively demarcate industries in the target city from the ones in Ho Chi Minh city.

21. Station Name	Phan Thiet
Topography	Flatland
Land Category	Cultivated land, Residential land
Distance (Existing Station)	Approx. 2 km (from existing Phan Thiet station)
Distance (Trunk Road)	Approx. 1.5 km (from QL1A)
Population	335,000
Industrial development potential	There are many ongoing projects for resort development in the target city, suggesting a fair potential for industrial development sightseeing and resort. It is desirable to effectively demarcate industries in the target city from the ones in Ho Chi Minh city.

22. Station Name	Long Thanh
Topography	Flatland
Land Category	Rubber tree plantation
Distance (Existing Station)	-
Distance (Trunk Road)	Approx. 3 km (from CT01)
Population	---
Industrial development potential	There is a possibility for enhancement of service industries including airport service and HSR service and tourism service industries. It is desirable to effectively demarcate industries in the target city from the ones in Ho Chi Minh city.

23. Station Name	Thu Thiem (Ho Chi Minh)
Topography	Flatland
Land Category	Redevelopment area
Distance (Existing Station)	-
Distance (Trunk Road)	-
Population	8.426 Million
Industrial development potential	The target city is the largest commercial town in Vietnam. A variety of industrial activities, including those of iron industry, service industry, high-tech industry, electric equipment industry, mechanical processing, and light manufacturing industry, construction and basic material industry and agricultural product manufacturing industry, is implemented. The city holds labor-intensive software parks and high-tech parks, as well as 15 industrial parks and export processing zones.

Source: JICA Study Team (The information in the 2013's study report was referenced partly)
Note: As for Dung Quat station, field survey was conducted considering the possibility of future development.

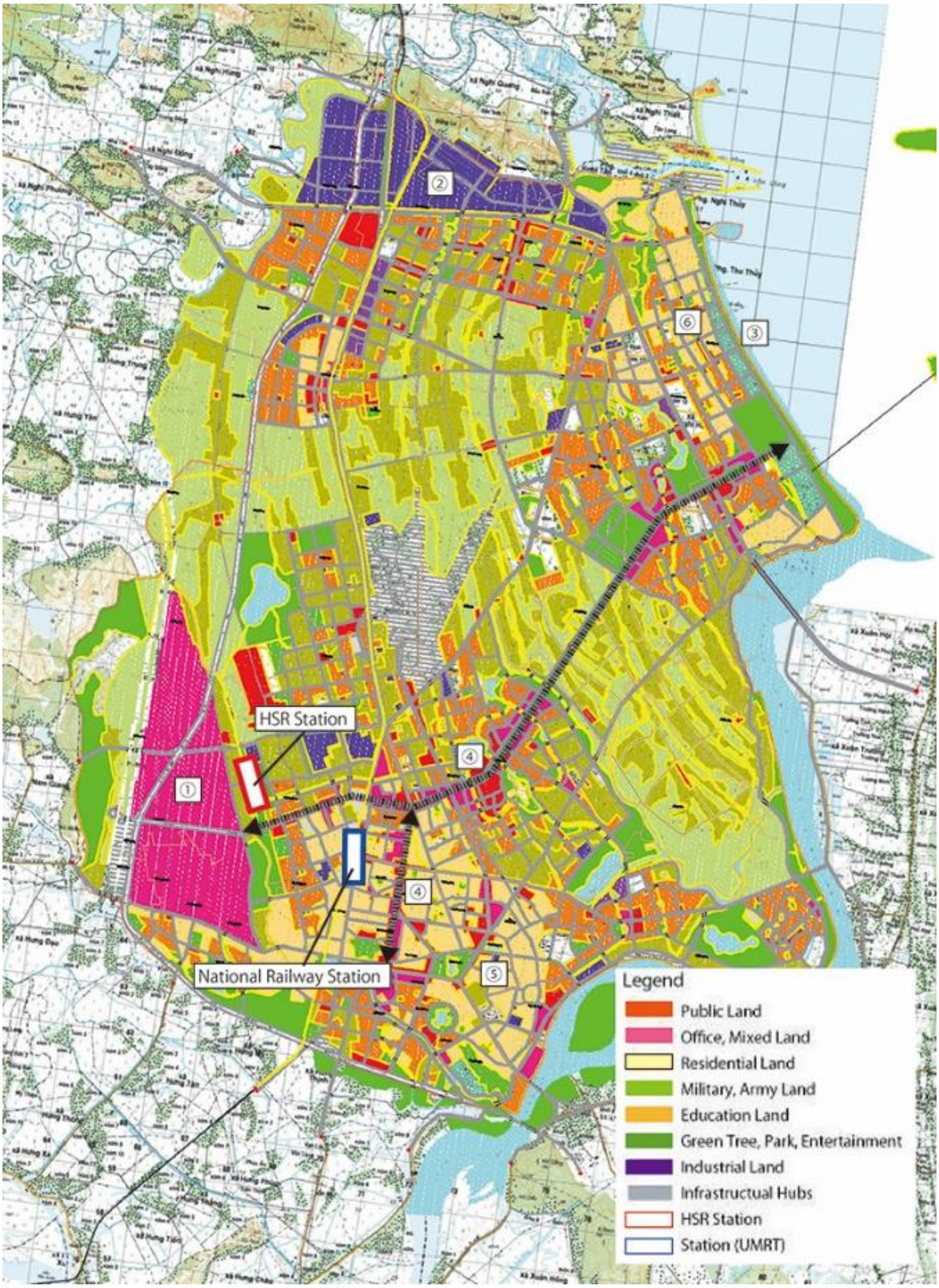
3.4.3 Examples of Regional Development Effect by TOD

Of all the stations along the HSR, five stations located in cities with a large population - namely Vinh station, Hue station, Da Nang station, Dieu Tri station and Nha Trang station – are selected. For each station, the current situation and plan of land use, TOD concept, orientation for station front development and region-wide development effect are outlined as below.

(1) Vinh Station

1) Current situation and plan of land use

The land use around the HSR station area is an agricultural zone, and the land use around the existing national railway station is residential and commercial zones. There is an industrial zone 15 km toward the north of the HSR station area ((2) in Figure). The coastal area to the northeast of the city is a tourist destination ((3) in Figure). As shown in Figure 3.12 of the land use map, the west side of the HSR station site ((1) in Figure), the surrounding areas of HSR station and national railway station as well as the areas along the major trunk roads ((4) in Figure) are designated as the mixed-use zone to promote residential, offices and commercial developments. The hinterland of the city ((5) in Figure) and the area along the eastern coastal line ((6) in Figure) are designated as residential land use to promote a better urban living environment. The area around the station is planned with the land use to promote better and convenient living environment and commercial and business activities, and the coastal area in the northeast is planned to have more open space with green landscape to enhance tourism attraction through the spatial design.



Source: Created by JICA Study Team based on Vinh M/P

Figure 3.12: Land Use Planning Map of Vinh City

2) TOD Concept

Vinh city is expected to be further developed as a tourism destination, and the province is the hometown of Ho Chi Minh, so that the region has been recognized as a major tourist resource area. The city is structured its urban center at the south of the airport with national railway station, international bus terminal, university, and others so that the large body of population is concentrated in this area, and with the tourism destination along the coast in the north side where hotels have been developed. It could be effective to introduce circulation bus services in the two core areas of city center and beach tourism zone. There should be then another connecting transit service system between these areas and airport to complete the comprehensive transport network system by selection and concentration. There is an industrial zone in the north end, and this zone may also be integrated for the transportation services to the businesses. Important TOD approaches are descried below.

- Bus service to circulate the southwest city center area shall be improved, and integrate national railway station, HSR station and long distance bus terminals.
- Bus service to circulate the northeast beach tourism zone shall be developed mainly to meet tourist demand.
- Bus route connecting city center area and beach tourism zone shall be established, and this route service includes the airport access to maximize the target users including tourists.
- Out ring service bus route shall be established to serve north industrial zone and other social service facilities from the city center.

Source: JICA Study Team based on Vinh M/P

Figure 3.13: TOD Concept Plan around Vinh Station

3) Station Front Development

The development of the city is immature and there are large areas that still need development according to the Vinh city urban development master plan. Among the planned land use, the area around the HSR station site is designated as residential and agricultural land. Besides, there are larger areas also designated as commercial use. While the city expects tourism development, since the city center is in a distance from the beach area, and the city center may be developed as commercial and financial district.

Based on the above situation, the proposed HSR station area may be re-designated with larger commercial land use zone to allow more retail services, amusement services, hotels and other mixed-use structures to come. The city is also the destination of the Lao route bus services, and the city is identified as a major international junction. Therefore, the station development should consider the integration of such modal service facilities in the station facility to achieve multi-modal concerned station service.

4) Region-wide development effect

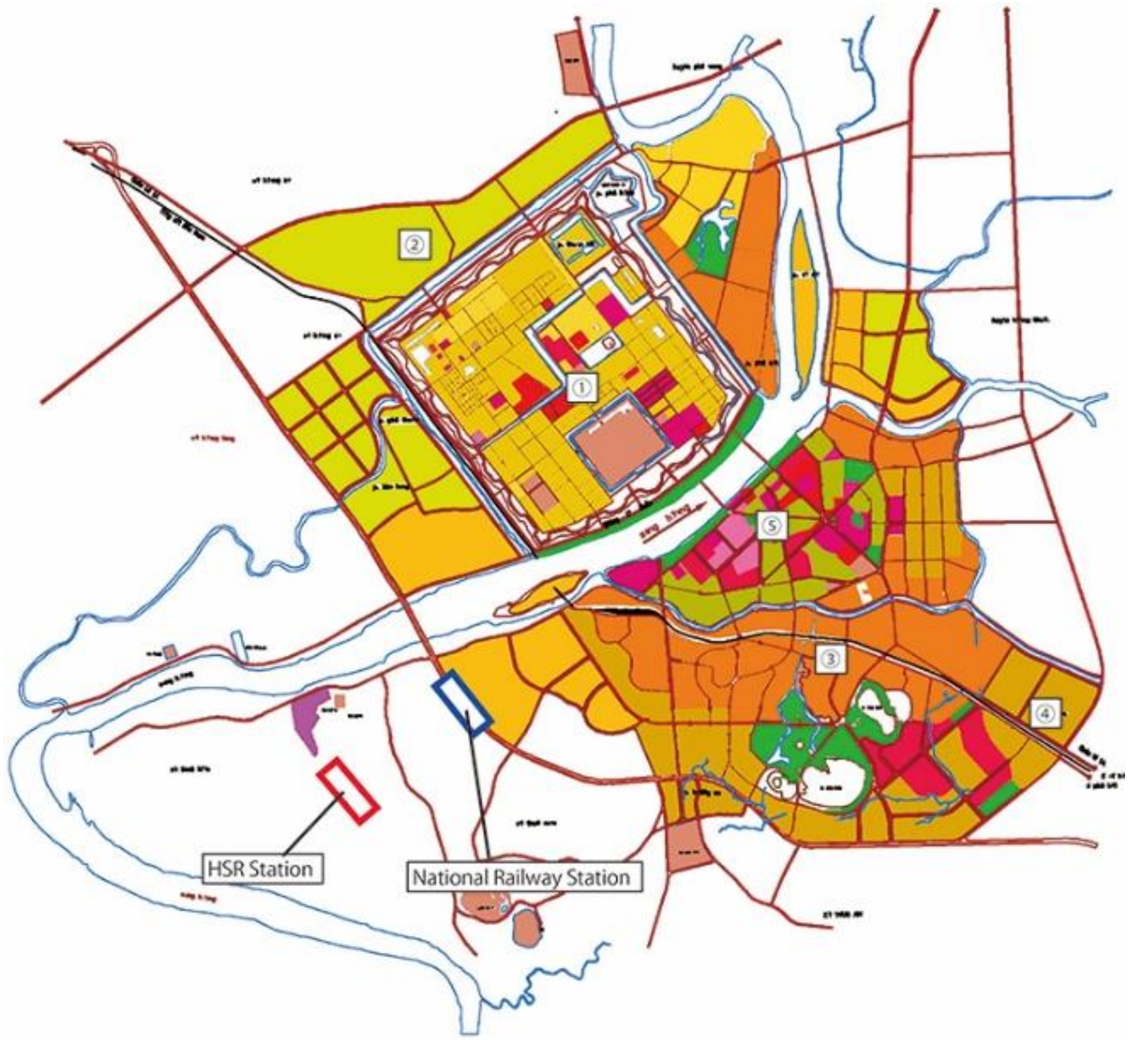
Vinh city aims to strengthen the tourism industry with beach resort and historical remains placed at its core. Also, there is an airport, an international bus terminal and other transport-related facilities developed in the city. By connecting the HSR station to each of these public transportation through a network, positive development effect for the enhancement of tourism and service industries is expected to be generated. This effect is further strengthened if a traffic network which supports tourists with their travel to surrounding areas is integrally coordinated with the in-city TOD.

(2) Hue Station

1) Current situation and plan of the land use

The land use of both HSR and national railway stations is for residents, and the characteristics of the city between the north and south divided by the river is different. The northern side of the city shows historical streetscape with its fort structure ((1) in Figure), and the southern side has more commercial oriented development ((5) in Figure). The hinterlands of the fort city and the commercial district consists of residential development ((2), (3), (4) in Figure), and the surrounding areas of these consist of mixed land use with agriculture.

As shown in Figure 3.14 of the land use plan, the development plan illustrates the development concept of the northern city area while rehabilitating the fort city structure, and existing land use is mostly maintained to enhance the potential of the historical urban fabric under the development plan.



Source: Created by JICA Study Team based on Hue M/P

Figure 3.14: Land Use Planning Map

2) TOD Concept

The city of Hue has been developed as one of the fort cities, and it is growing as a tourism-oriented city with a population of over 350,000. The city is split into half by the river, and the northern half is the historic fort city, and the southern half is a growing commercial district. New residential area development is also proceeding further to the east. Under such urban structure, the historic zone, commercial zone and new residential zone need to be served by separate transport services. Besides, a transit service network that serve among the HSR station, national railway station, airport and bus terminals are necessary, and these urban zones and their transport services could be connected as one network in Hue city. Important TOD approaches are described below.

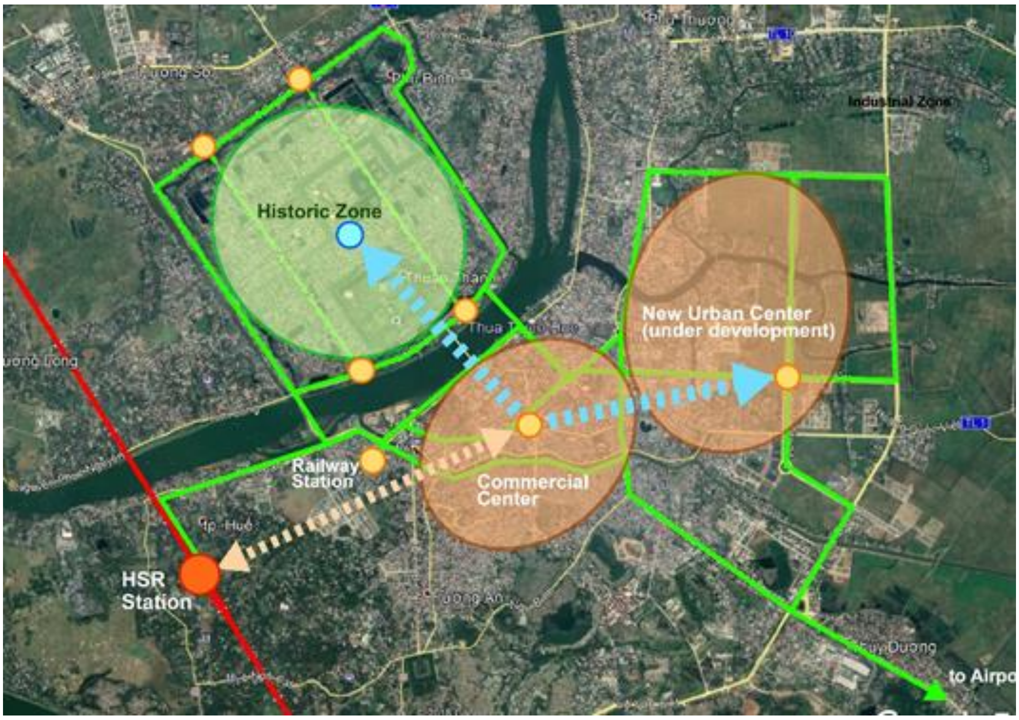
- For the commercial zone, outer ring large bus service and inner minibus service may be established to reduce traffic congestion and enhance transit services. This includes development of a bus mall and taxi services.
- For the historic zone considering heritage environment, retro design minibusses may be introduced with higher service frequency in order to meet the tourist demands.
- For the new residential zone in the east, flexible service system with bus types and service programs needs to be introduced as the zone is under development.

- Bus network connecting all three zones, and special bus lanes may be designated for smooth operation where necessary. This transit network should integrate the HSR station, national railway station, long distance bus terminals and airport.

3) Station Front Development

Hue City has large potentials of tourism industry and promotion of cultural research utilizing its historical elements and heritage. Major role of the HSR station is to provide services to the visitors, such as tourists, researchers and business person. From this point of view, it is important to establish effective transportation service from the HSR station to the city center. Currently, the station site is proposed in a small hilly area with low-density housing establishment.

Based on the above condition, it is recommended to implement resettlement of the residents and designate about 200 m space from the station building as a public space with multimodal transit terminal facility and public park(s) in order to buffer the area from the surrounding residential areas considering environmental impact.



Source: JICA Study Team based on Hue M/P

Figure 3.15: TOD Concept Plan around Hue Station

4) Region-wide development effect

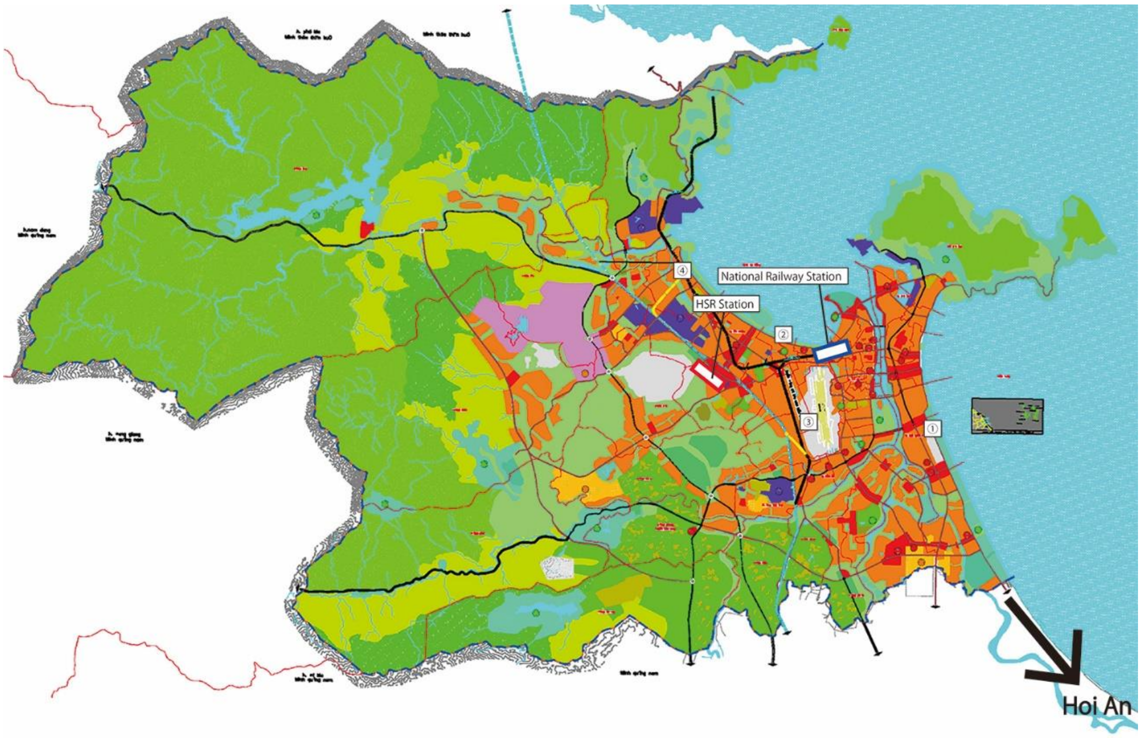
The city seems to need the development of traffic network necessary for people living in newly-developed residential areas as well as the enhancement of the urban traffic network to deal with an increasing demand of tourism industry. It can be expected that the regional industries are advanced further by creating a network which enhances the convenience of the HSR station and supports the smooth travel of people across the entire city.

(3) Da Nang Station

1) Current situation and plan of land use

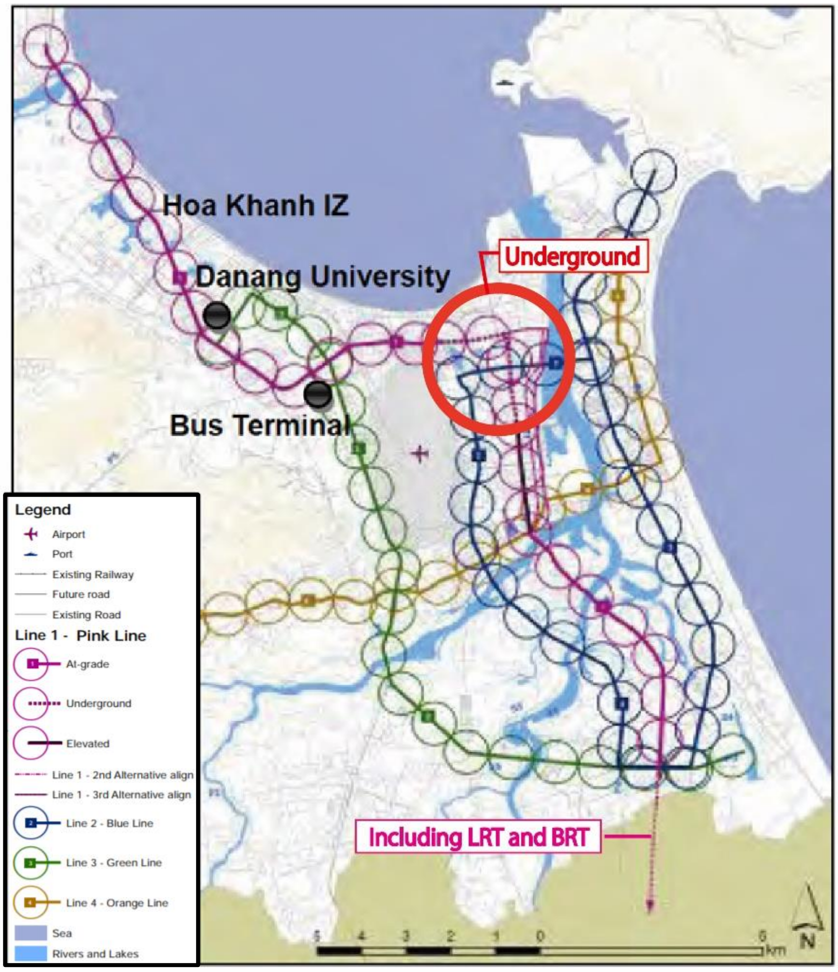
The land for the planned HSR station and the national railway is currently used as a residential area. In the coastal area in the eastern part of Da Nang city (Figure 3.16 (1), (2)) lies a sightseeing spot with beach resort, attracting a number of tourists. There is an airport located in the middle of the city (Figure 3.16 (3)), which makes inter-city accessibility for tourists very high.

According to the Urban Development Master Plan of Da Nang city, the population of the city is expected to be 2 million in the future, suggesting a further growth. Therefore, as the Master Plan states, it is essential to form a compact urban area based on a public transport system. In line with this policy, Da Nang city bypass, which runs in North-South direction (Figure 3.16 (4)), is described as the most important road connecting three major business zones in Da Nang city. Considering future traffic demand, a transport system consisting of the Light Rail Transit (hereinafter referred to as LRT) or the Bus Rapid Transit (hereinafter referred to as BRT) is planned to be introduced in the Da Nang city bypass. It is also proposed in the Master Plan that the first 5 km from the urban center shall be installed with an underground system (Figure 3.17).



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

Figure 3.16: Land Use Planning Map of Da Nang City



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

Figure 3.17: Location of UMRT Project (Urban Mass Rapid Transit)

2) TOD Concept

As illustrated in Figure 3.17, 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 a tourism city attracting many visitors. However, since there is little cooperation and coordination between these places at present, the maximized use of these tourism resources has not been successful.

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. Basic urban transport network system is to establish a tourist route of coastal network line connecting Hoi An as a part, a route connecting railway stations and airport, and a route connecting major city area functions and attractions, and it is then important to connect all these core routes as one organism to achieve smooth transit network in the city. Important TOD approaches are described below.

- In order to encourage the smooth inter-city travel of people, BRT or LRT shall be introduced to Da Nang city bypass depending on the traffic demand as shown in the Da Nang Urban Development Master Plan.

- The route connecting Da Nang beach area and Hoi An could be serviced by LRT (light rail transit system) that partially operates at higher speed to maximize train operation time with best service. This could be extended through the city center area of Da Nang and to north beach area.
- HSR station, airport, national railway station and major long distance bus terminals may be connected by bus with designated bus lane or bus mall or LRT for terminal transit network service.
- Urban area and Hoi An area may have inner bus circulation service to enhance individual transport service quality, then these service areas could be connected with Da Nang beach LRT or terminal transit network. Urban area transit system needs to serve city administrative zone, educational and cultural zone, commercial zone and recreational zone among others.

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

Figure 3.18: TOD Concept Plan around Da Nang Station

3) Station Front Development

The proposed development site of Da Nang HSR station is located on the edge of the new residential development area in the northwest of the city, and it is also considered as a hinterland of the Da Nang bay area so that the site has strong relation to the north beach area redevelopment. The development center for tourism is in the area east of the international airport and its surrounding city area as well as Da Nang beach area. When the HSR is developed in the future, the natural tourism resources in around 200 km radius could become more accessible, and the station target area may become a district for the business person and tourists expecting land transportation from Da Nang including arriving tourists. Including visiting tourists, the station area should be able to provide services, such as wide-area tourism and industrial information, short term hotel services, commercial functions and others, that fulfill the needs of the visitors.

Based on the above development scenario, the surrounding area of approximately 300 m to 500 m square zone around the HSR station shall be designated as commercial land use zone to house commercial functions, hotels, information centers and others together with the urban transport terminal building in order to meet a wider range of demand and needs. The station area could be developed by medium density level.

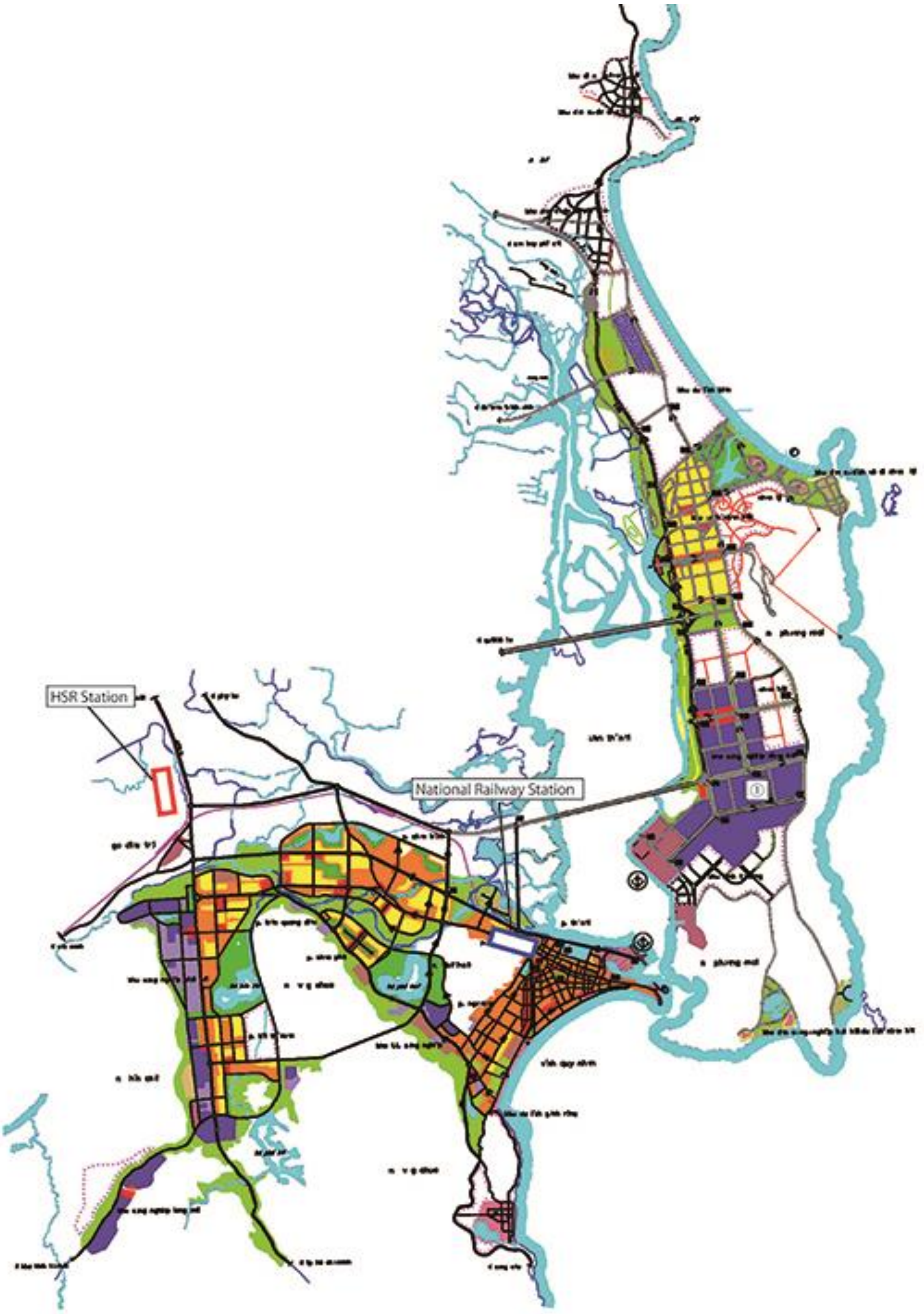
4) Region-wide development effect

It is desirable that three divisions, Da Nang city, Hue province and Quang Nam province (in which Hoi An, a city famous for its heritage sites, is situated), share one tourism development strategy. By establishing a public transport network linking each city/province, tourists are encouraged to stay longer in these regions. Also, the provision of a wider variety of tourist services will lead to attract a larger number of return customers. In this way, the maximized use of tourism resources in these three divisions are made possible.

(4) Dieu Tri Station (Qui Nhon)

1) Current situation and plan of land use

Qui Nhon city is an industrial city, with the ongoing development of a large-scale industrial park on the peninsula located in the northeast of it (Figure (1)). The city has a waterfront and tourist resources, divided into five major zones - namely, port zone, administrative zone, commercial zone, tourism zone and academic zone. These five zones have a population of 650,000. Dieu Tri station, the entrance to Qui Nhon city, is 10 km apart from the urban center of Qui Nhon.



Source: Created by JICA Study Team based on Qui Nhon city M/P

Figure 3.19: Land Use Planning Map of Qui Nhon City

2) TOD Concept

The city of Qui Nhon is located in the area of major industrial development occurring in the peninsula to the northeast of the city center. There is a beach zone to develop tourism attractions, trading port, administrative zone, commercial zone, tourism zone and educational and cultural zone, and there are over 650,000 people living in the city. The target site for the HSR station of Dieu Tri is about 10 km away from the urban center. In order to effectively develop a transportation network in the region among those spread areas, three major zones should be considered for transit system services: Industrial zone, Qui Nhon city center area (including above noted five zones) and Dieu Tri HSR station development area. Each will be served by the local bus service system, and three areas will be connected by medium distance transit system to provide proper transport services. Important TOD approaches are described below.

- Bus circulation system to serve industrial zone and to connect city center at scheduled operation will be established. However, the workers for the factories in the zone may be serviced by the commuter system operated by the industrial park or individual companies, and this could be the basis.
- Bus circulation system connecting five zones in the city center as well as surrounding residential areas, will be established. Major functions in the city area would be connected for convenient service and for reducing traffic congestion.
- The HSR station target area shall be redeveloped including existing VNR railway station area, and bus network system shall be introduced in the area.

LRT or articulated bus could serve the above described three major areas to achieve wide regional transit network.

3) Station Front Development

The surrounding area of the proposed HSR station site is not developed much, and agro land covers a large area, and low density suburban residential development may be considered from now on. The area is about 10 km from the Qui Nhon urban center, and improving accessibility to the city center is important. However, the demand may be difficult to estimate due to the unclearness of the characteristics of the residents in the future, and the system and program of the transit system may vary. The demand from the station area to Qui Nhon city area may be high. However, the majority would be tourism-oriented. Therefore, it could be assumed that the tourists may directly move to the city center of Qui Nhon, and business-oriented visitors may use the HSR system to move around the business target cities.

Based on the assumed above condition, Dieu Tri HSR station area may be developed with short term hotel facilities and common retail services. Therefore the area should be designated as semi-commercial development zone to allow both residential and commercial development. Besides, transit service terminal should be developed to connect with Qui Nhon city by LRT or articulated bus system to meet the users' needs. For better service establishment for industrial zone related activities, "Satellite One-Stop Service Center" type government services may be convenient as if these are stationed at the HSR station area.

Source: Created by JICA Study Team based on Qui Nhon city M/P

Figure 3.20: Land Use Planning Map around Dieu Tri Station

4) Region-wide development effect

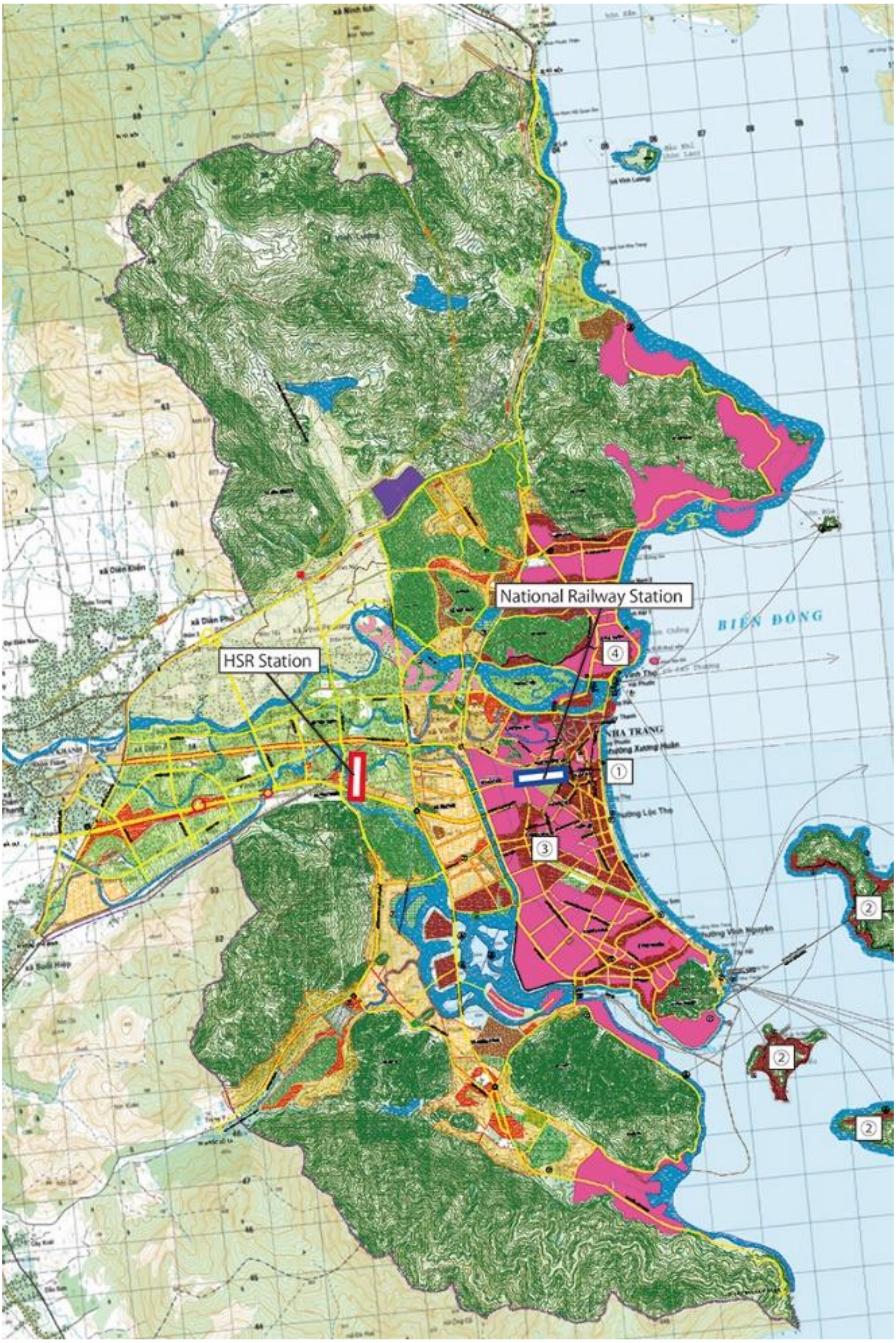
In Qui Nhon city, the backland for the area planned for the HSR station, a large-scale development of industrial park has been progressing on the peninsula. This development is coupled together with port construction and tourism district development, contributing to the whole waterfront development. As the future increase of demand for public transport is expected, the development of mass transit system for commuting is necessary. It is possible that the role-sharing of transport system between urban center and tourist destination and the formation of region-wide traffic network based on the connectivity with the HSR will greatly contribute to the growth of the local industry.

(5) Nha Trang Station

1) Current situation and plan of land use

Currently, the land for the HSR station is a bare ground, and the land around the national railway station is used as a commercial area. Nha Trang city is one of the most popular tourist sites among regional cities of Vietnam after Da Nang. Along the curved coast stretching from north to south, there are a number of hotels and restaurants together with other related services ((1) in the Figure), and except the former airport area, urban development has been progressing.

As a tourism island is nearby (in the Figure), the city constitutes a tourist site famous for its beach resort which has a port an international cruise ship stops at. There is an administrative zone, commercial zone and academic zone in the city ((3) in the Figure). In the north of the city lies a university. ((4) in the Figure). The population is concentrated in the coastal areas of the city.



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

Figure 3.21: Land Use Planning Map of Nha Trang City

2) TOD Concept

The long beach tourist zone and north beach zone should be connected with an LRT type service system to meet larger demand of movement. The transit network connecting the national railway station, bus terminals, administrative zone, commercial zone, etc. needs to be integrated with the HSR station so that the network system will contribute to a wide tourism area development. Currently, the operating international airport is located at about 30 km south of the city area, and the transport service to the airport may be considered separately from others servicing major hotels, terminals, shopping centers and cultural centers so that the airport service role could be clearly identified. Important TOD approaches are described below.

- Triangle Zone including existing railway station and major city districts should be connected by city bus service. Developing bus mall and the multi-service route set up for bus service may reduce traffic congestion. Large area circulation and district level circulation in the urban area is important to serve with effective hierarchy of bus service system.
- Beach road area and north beach zone and university district may be networked with the LRT system, and the service should extend to the port area at the south end of the city.
- Regional transit network service system including LRT and bus services in the city area should integrate the destinations of HSR station, national railway station and regional bus terminals to improve accessibility and widen the target users.
- Access to the international airport will be separately established to serve major destinations in the city center and beach district along the designated pick-up route, as this may be specifically set as tourist transport service.

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

Figure 3.22: Land Use Planning Map Around Nha Trang Station

3) Station Front Development

The area designated for the Nha Trang HSR station development is currently under development as a low-density residential zone with some small scale factories. There is a bypass road that has been developed so that further housing development may continue. Nha Trang city is rather developed independently from other destinations instead of creating a large regional tourism realm, and the city is expected to further grow by tourism and related service promotions. In this point of view, the city should be developed completing all necessary functions and services to fulfill tourist demands and needs.

Based on the above concept, it is important to develop facilities to enhance accessibility and network services from the HSR station to the urban center instead of establishing commercial activity center around the station. The station front area should be developed with an effective area of bus terminal, which could provide more frequent services, and taxi service section with information service center and small scale retail facilities. Environmental consideration for the community around the station site should be taken into account and public open space and park with water feature should be developed around the station front area so that the “Ground Entrance to Nha Trang” could be realized.

4) Region-wide development effect

Nha Trang is a city where a large-scale beach resort, which has a port an international cruise ship stops at, and the related tourism industry are being developed. Further enhancement of inter-city traffic network including a tourism island, university zone and administrative zone is necessary. To meet the demand of inter-city travel of tourists, which is expected to increase in the near future, it may be necessary to effectively connect each transport node by making a hierarchical structure of urban transport system, including Light Rail. The impact of the enhancement of urban transport network on the expansion of tourism industry could be significant.