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Program

2016/17 Policy Consultation III :

Implementation Plan for Construction of High-Speed Railway Infrastructure in Myanmar

Ministry of Strategy and Finance

Korea Eximbank
THE EXPORT-IMPORT BANK OF KOREA

2016/17 KSP Policy Consultation Ⅲ

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Executive Summary

The purpose of the project is to share South Korea's experience and related technology of introducing high-speed rails and establish implementation ways of establishing high-speed rail infrastructure in Myanmar through a KSP project for providing political advice on construction and infrastructure.

In this study, the HSR demand and construction cost in the case of the construction of a HSR in Myanmar have been estimated, and the economic and other conditions of the country have been reviewed. And the timing of its construction in Myanmar has been studied, and then policy directions have been presented. Incorporating the opinions of MR, the study scope has been limited to the suggestion of a plan to utilize a new HSR line. The scope of the study was limited to presenting ways of utilizing the new high-speed rail, incorporating MR's opinions.

Also, during this project, some officials of MR were invited and trained for their capacity building on the high-speed rail.

For the HSR, eight stations were suggested with an average inter-station distance of 82.5 km, which is similar to 76 km or the average inter-station distance of the countries having operated HSRs. For the HSR stations, we have suggested that the existing rail stations be utilized for some of them with others relocated to the outskirts of the cities.

The HSR demand forecast indicates that the daily HSR demand in the mid-2040s is expected to be about 100,000 to 130,000 people. For information, this is similar to the number of daily users of Gyeongbu HSR in Korea. To secure the HSR demand at that level, the following point can be considered as a key factor to be taken into account necessarily in pursuing the HSR construction in Myanmar: the assumed high economic growth rate of 7.2% should be continued up to the year 2040.

The construction cost of a 600 km HSR between Yangon and Mandalay is estimated at 20,363

Million USD or 28.1% of the GDP of Myanmar in 2017 (72,368 Million USD), and it amounts to 205% of the Myanmar Government's expenditure of 9,935 Million USD. Of course, the construction cost will be input over a period of about ten years, but when considering the present economic scale of the Government and its budget scale, it is deemed impossible to pursue the construction of the HSR for the whole Yangon~Mandalay route soon.

If, however, it is taken into consideration that the economy of Myanmar recently grew at a high rate of 7~8% and that this growing trend is most likely to be continued in the future, it is deemed necessary to consider promoting the HSR project in Myanmar from a mid- and long-term perspective. If the construction of the HSR is implemented actively in the latter half of the 2020s, when Korea's experience is taken into account, its completion and opening is anticipated to be possible in the early and mid 2040s.

It is deemed impossible due to the economic condition to implement the HSR construction for the whole planned route between Yangon and Mandalay any time soon, but it will be necessary to conduct a detailed feasibility study for the construction of a 68 km HSR between Yangon and Bago. As the construction of Hanthawardy International Airport is being pursued in Bago, the construction of the HSR needs to be examined in line with the present situation of promoting the airport construction. Also, in the viewpoint that the Yangon~Bago section may serve as a pilot track for the whole Yangon~Mandalay HSR route, the construction of the HSR in the section needs to be considered positively. If the technology and experience from the design, construction and operation of the Yangon~Bago (pilot section) HSR are utilized, the trials and errors in the construction of the HSR in the whole route will surely be reduced and a successful construction will be made. Also, if the pilot section HSR construction is linked to the new town development plans for the outskirts of Yangon and Bago, the effect of the project is expected to be maximized.

Ⅰ. Project Overview

1. Background & Purpose

1.1. Background

- In Myanmar, both passenger and freight transportation demands were on the increase together recently with economic growth, but because the rail infrastructure and vehicles are deteriorated, it is difficult to meet the demands, and the level of rail services are low in terms of punctuality, etc.
- Recently, Myanmar Railways (MR) has been pursuing extensive improvement projects for the deteriorated rail facilities with priority in order to attract foreign investment and promote economic growth.

※ KSP projects on Construction & Infrastructure Policies

KSP projects are knowledge-based economic cooperation projects that provide tailored policy advice to partner countries based on Korea's development experience and knowledge. The KSP was introduced by the MoSF in 2004, and the program for the sector of construction and infrastructure was newly introduced in 2014.

- Referring to South Korea's experience in establishing KTX trains (high-speed rail trains), MR requested the Korean Government to implement a project of KSP (Knowledge Sharing Program) in order to establish rail systems in Myanmar effectively.

• Thus, accepting MR's request, the Ministry of Strategy & Finance of South Korea decided to share the country's rail construction and operation experiences with MR through advisory services on the construction and infrastructure policies of KSP in 2016.

1.2. Purposes of the Project

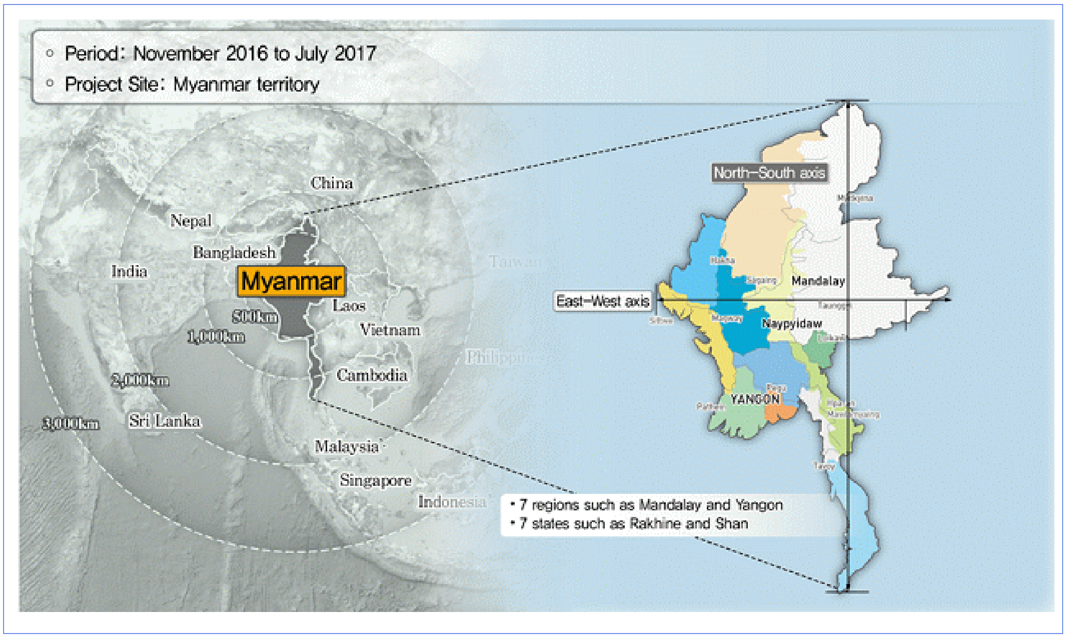
• To transfer to Myanmar Korea's experience and expertise obtained through KTX construction and operation through a KSP project in the field of construction and infrastructure and to create an implementation plan to establish a high speed railway in Myanmar

2. Project Scope

2.1. Project Period & Location

• Project Period: 2015 to 2060 (Base year 2015; Target years 2030, 2040, 2050, 2060)
• Project Location: Myanmar (Yangon~Mandalay)

Figure 1 | Project Scope



2.2. Activities for the Project

2.2.1. Diagnostic analysis of the present situation of railways in Myanmar

- General preview of social and economic situation in Myanmar
- Current situation of railway infrastructure and situation of their use. The feasibility of high-speed rail construction is to be determined considering economic situation and rail infrastructure conditions.
- Travel pattern analysis both in passengers and freight
- Railway-related issues, regulations, policies, and development plans

2.2.2. Case study on Korea's experience in introduction and operation of high-speed railway

- Overview of Korea's rail industry that developed along with industrialization
- Case studies on the construction and operation of KTX
  - Background of introducing a high-speed rail, related issues (laws and regulations, policies, development plans), introducing process, analysis of current operating conditions
- Analysis of socio-economic effects associated with the operation of KTX

2.2.3. Policy Recommendations for Construction of a high-speed rail in Myanmar

- Drawing up policy recommendations through an analysis of the present situation of Myanmar and a review of Korea's model case
- Improvement of current rail infrastructure
  - Methodologies to construct and introduce facilities and systems suitable to the high-speed rail
- Procurement of high-speed rail rolling stock
  - Reviewing rolling stock suitable for the high-speed rail and suggesting a procurement method by considering the financial status of Myanmar
- Transport demand forecast for high-speed rail in a route between Yangon and Mandalay

2.2.4. Capacity Building Workshop

- Establishing capacity building workshop agenda in consultation with Myanmar
- Workshop overview
  - Expected attendees: 5 Myanmar government officials related with railways
  - Period: 29 May to 3 June 2017
  - Workshop contents: Experts' lectures, visits to relevant agencies, etc.

3. Expected Effects

- Transfer of Korea's high-speed rail development experience and assistance to Myanmar in establishment of a rail-oriented transportation system
  - Assisting Myanmar in implementing a rail project through a transfer of Korea's experience in introducing a high-speed rail and developing rolling stock
- Assisting Myanmar in establishing policies for a systematic setup of a rail system
  - Assisting in determining reasonable investment policies
  - Assisting in upgrade of transportation infrastructure by establishing new rail construction policies
- Capacity building and sharing of Korea's experience through trainings for invited trainees and seminars
  - Contributing to Myanmar's railway development policy formation through transfer of Korea's experience and technology

Ⅱ. Analysis of Myanmar Transportation Condition

1. General

1.1. Overview

• Myanmar is the largest country among the countries in the Indochina Peninsula with a north-to-south distance of 2,051km and an east-to-west distance of 936km. Its entire area is 676,577㎢ which is equal to about 7 times the area of the Republic of Korea. General situation of Myanmar is as follows: (KOTRA Yangon Trade Center, 'KOTRA's National Information of Myanmar,' 2016)

Figure 2 | Location Map of Myanmar

Source: Google Images

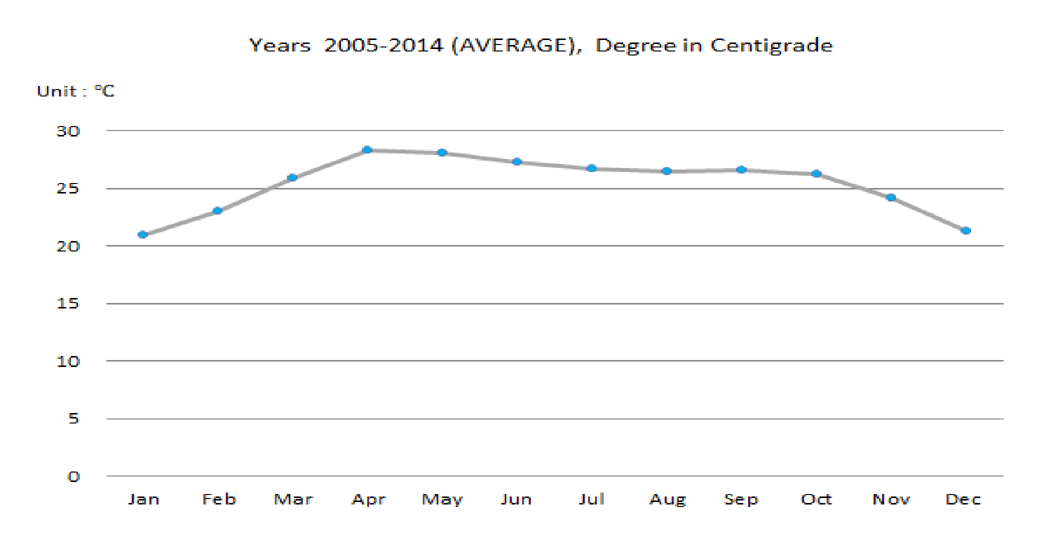
- Area: 676,577㎢
- Population: 56.8 million (as of 2017)
- Tribes: Burma (69%), Shan (9%), Karen (7%)
- Ethnicity: Burma 70%, minor tribes 25%, and others
- Climate: Tropical monsoon (annual average 27℃)
- Religions: Buddhism (89.4%), Christianity (4.9%), Islam (3.9%), other (1.8%)
- Currency & exchange rate: Kyat [US$1 = 1,355 kyat (as of 2017)]
- Administrative division: 7 states & 7 regions, 68 districts, 333 townships
- Industrial structure: Agriculture (37.1%), industry (21.3%), service industry (41.6%) (2015, CIA)
- Natural resources: Natural gases, timbers, beans, clothing, etc.

1.2. Climate & Geology

1.2.1. Seasons & Temperatures

- Although Myanmar is located in Asian monsoon zone, it is greatly affected by its geological location and features.
- Its longitudinal length reaches 2,051 km; tropical and subtropical climates appear across the country; and it has a tropical monsoon climate of steamy heat.
- Its annual average temperature is 27℃, which is not too high for a tropical country. In years 2005~2014, the monthly average temperature was highest in April and lowest in December and January. Also, the monthly average temperature difference is around 10℃.
- As for the seasons, March~April is summer, November ~ February is winter, and February ~May is dry season, and May~October is rainy season. In rainy seasons, thunderstorms accompanied by heavy rainfall and southwesters occur every year. (KOICA, ‘Myanmar Trunk Road Network Master Planning Project,’ 2015)

Figure 3 | Monthly Average Temperatures of Myanmar



Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

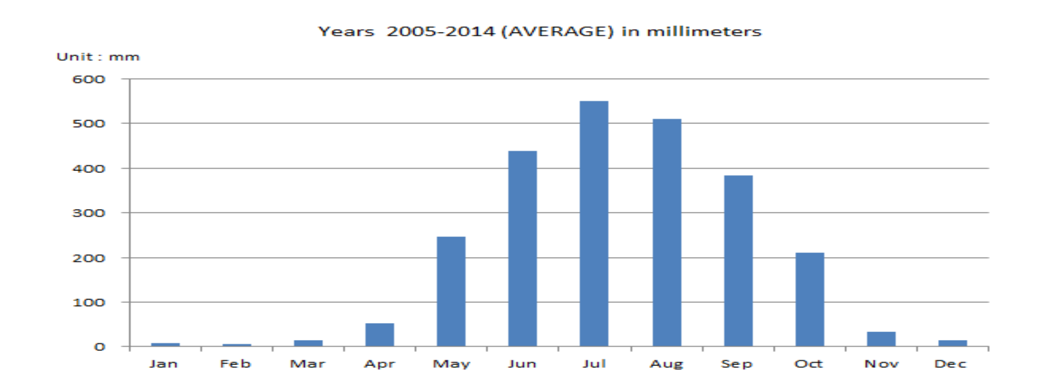
1.2.2. Rainfall

• Myanmar has rains chiefly by a southwest monsoon and has a rainy season between mid May and mid October. But rainfalls vary with locations, altitudes and months. The rainfall is heaviest in July, and over 5,000mm of rainfall is recorded every year in the coastal areas and in the west and southeast while about 2,500mm is recorded in the Delta. Dry and rainy seasons are distinct; the rain season is from late May to mid October with an average rainfall of 5,000 mm in the middle region and 2,500 mm in Yangon. In November ~ February, which is the coolest season in the dry period, the average lowest temperature is 17℃, but the average highest temperature in March~May goes beyond 40℃.

- Dry period: mid February to mid May
- Rainy period: mid May to mid October
- Winter: mid October to mid February

• The maximum rainfalls were recorded in Rakhine, Kachin, Kayin, some parts of Kayin, coastal areas of Tanintharyi, and some parts of Mon. The rainfall decreases as it goes toward the north, and the rainfall in dry areas ranges from 500mm to 1,000mm a year. (KOICA, 'Myanmar Trunk Road Network Master Planning Project,' 2015)

Figure 4 | Monthly Average Rainfalls of Myanmar

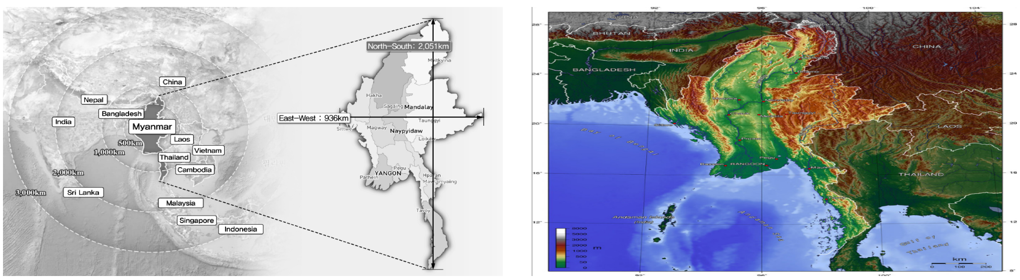


Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

1.2.3. Geographical Features

- Total north-to-south distance of the land of Myanmar is about 2,051km and the longest distance from east to west reaches 930km. Its total area is 676,577㎢, which is about 7 times that of the Republic of Korea. The altitude is formed from north to south, starting from Mt. Hkakabo 5,881m high in the north to the Delta in the Ayeyarwady River and the Sittang River in the south. Geographically, the country can be divided into five areas: mountainous areas in the north, the mountain ranges in the west, the highlands in the east, the central basin and lowlands, and the coastal plains. Total length of the national boarder area is 5,876km; the country adjoins Bangladesh in a length of 193km, China 2,185km, India 1,463km, Laos 235km and Thailand 1,800km. Also, abundant natural resources and crude oils are buried along the 1,930km coastal line. (KOICA, 'Myanmar Trunk Road Network Master Planning Project,' 2015)

Figure 5 | Location & Geographical Maps of Myanmar



Source: Wikipedia「http://ko.wikipedia.org)」

1.2.4. Natural Disasters

- According to the Office for the Coordination of Humanitarian Affair of the UN, Myanmar is classified as one of the countries that have the highest risk of natural disasters in the Asia-Pacific region. Also, the victims by three typhoons and floods and two great earthquakes over the last decade reached 3.1 million, and as mentioned above, the damages by natural disasters to the transportation infrastructure are severe.

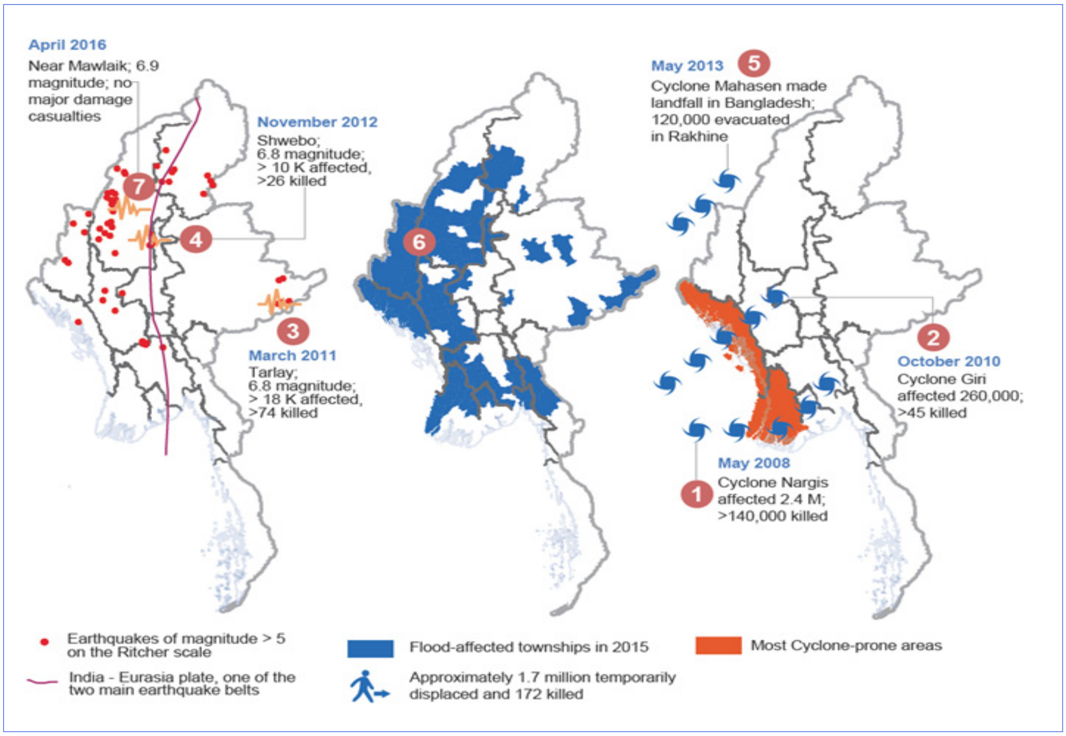
- According to the Myanmar Department of Meteorology and Hydrology, serious temperature changes, precipitation pattern changes, increased risks of fire and water shortage occurred due to an extreme El Nino in Myanmar after mid February of 2016. Thus, in order to minimize damages by natural disasters to transportation facilities and introduce an advanced maintenance system, it is a must to establish proper measures through the project.

Table 1 | List of Natural Disasters That Happened in Myanmar (2008 ~ 2016)

No.	Date	Disaster Type	Region	Damages
1	Mar 2008	Typhoon	Ayeyarwady Delta	• About 140,000 people are dead or missing. • An estimated 2.4 million people lost their homes and livelihoods.
2	Oct 2010	Flood	Whole country	• 45 people were killed, 100,000 people became homeless. Some 260,000 people were affected.
3	Mar 2011	Earthquake	Shan State	• Over 18,000 people were affected. • At least 74 people were killed and 125 injured.
4	Nov 2012	Earthquake	Northern Myanmar	• At least 16 people were killed and 52 injured. • Over 400 houses, 65 schools, and some 100 religious buildings were damaged.
5	May 2013	Typhoon	Northern Myanmar, Rakhine	• Occurred near Bangladesh. • Over 120,000 people were affected.
6	2015~16	El Nino	Whole country	• After 1950, the most devastating El Nino occurred. • The climate patterns of Myanmar were most seriously affected.
7	Apr 2016	Earthquake	Mawlaik	• An earthquake at a magnitude of 6.9 occurred. • No major human damages took place.

Source: OCHA, 「Myanmar: Natural Disasters 2002-2012」, 2012

Figure 6 | Natural Disasters That Occurred in Myanmar



Source: OCHA, 「Myanmar: Natural Disasters 2002-2012」, 2012

1.3. Socio-economic Condition

- Myanmar is getting out of its 50-year economic and political isolation it had suffered after its liberation and has a high potential of economic development due to abundant natural resources and the strategic location of the land.

- Recently, the government of Myanmar's efforts for economic and policy changes were observed such as the privatization of state-owned companies, the implementation of foreign investment attraction programs, and the operation of special economic zones. And together with the launch of a civilian government, the country's economic opening and transportation infrastructure construction are accelerating.

- Myanmar is an agriculture-based country; agriculture takes up 30% of the whole industries, and about 70% of the total population or about 50 million people are engaged in it.

- Also, it has a resource-based structure in which it relies upon crude oils, gases, coal and the forestry industry.

1.3.1. Administrative Division

- Myanmar is composed of seven states (Chin, Kachin, Kayin, Kayah, Mon, Rakhine, and Shan) and seven regions (Ayeyarwady, Magway, Mandalay, Bago, Sagaing, Taninthary, and Yangon).
- Also, it is made up of 74 districts and 330 townships under the states and regions.

Table 2 | Administrative Division of Myanmar

Region and State	Area		District	Township	Map of Myanmar
	Km2	Mile2			
Myanmar	261,228	676,553	74	330	
Kachin State	34,379	89,039	4	18	
Kayah State	4,530	11,731	2	7	
Kayin State	11,731	30,382	4	7	
Chin State	13,907	36,018	3	9	
Sagaing Region	36,535	94,621	10	37	
Tanintharyi Region	16,736	43,343	3	10	
Bago Region	15,214	39,403	4	28	
Magway Region	17,305	44,819	5	25	
Mandalay Region	11,566	29,954	7	28	
Mon State	4,748	12,296	2	10	
Rakhine State	14,200	36,777	5	17	
Yangon Region	3,927	10,171	4	45	
Shan State	60,155	155,796	13	55	
Ayeyarwady Region	13,567	35,136	6	26	
Nay Pyi Taw	2,729	7,068	2	8	

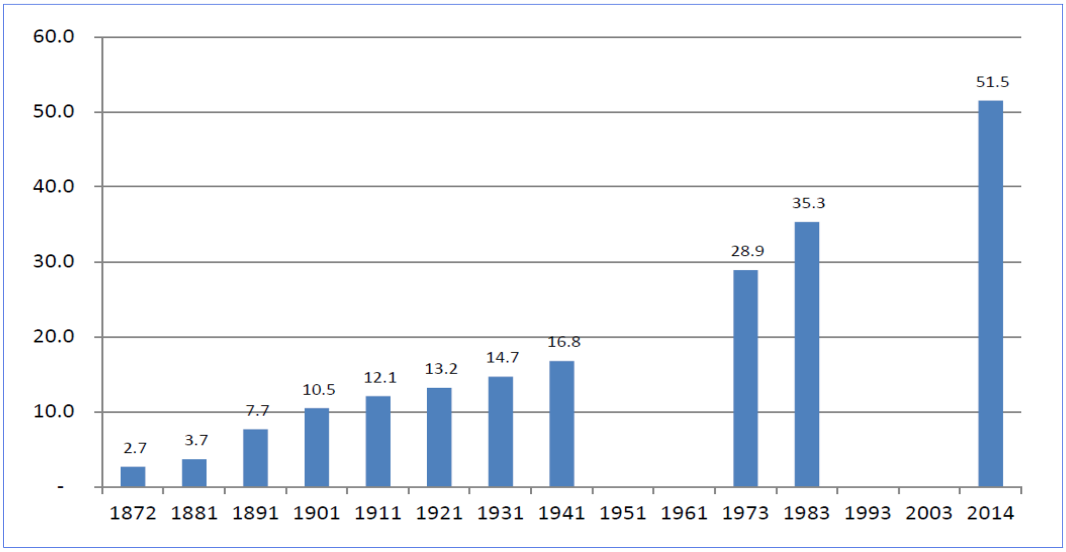
Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016
Wikipedia「http://ko.wikipedia.org)」

1.3.2. Population

- According to the Population and Housing Census of Myanmar (2014) carried out by the Ministry of Immigration and Population in August 2014, total population of Myanmar is estimated at 51.5 million.

• Between 2003 and 2014 the annual average growth rate of the population of Myanmar was 0.89%, which shows a decreasing trend when compared with 2.02% or the annual average growth rate of 1973.

Figure 7 | Yearly Population Trend



Note: The census was not performed in 1951, 1961, 1993 and 2003.
Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016 Union of immigration and Population, 「The 2014 Myanmar Population and Housing Census」, Union of Myanmar, 2014

1) Population Trend by Administrative Division

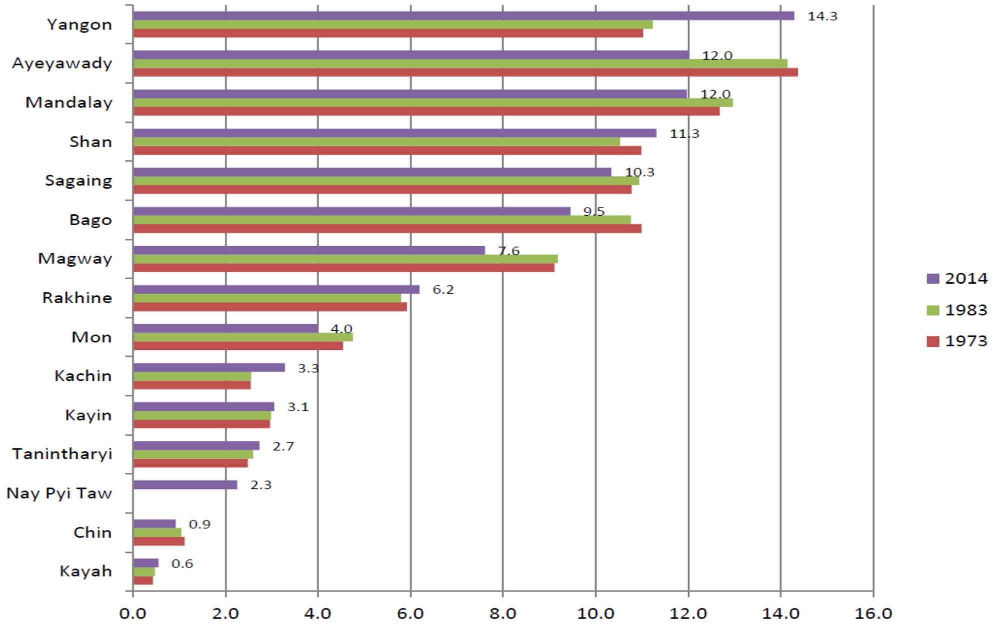
• The former capital city Yangon is the city with the largest population in the country and is the hub of trade and commerce, and the second largest regions are Ayeyawady Region and Mandalay Region, which have robust trade with China.

• Also, Nay Pyi Taw is currently the administrative capital and there are major government agencies in it.

• Due to the topographical features of the country and the lack of connectivity of transportation facilities, the population is concentrated in the central part of the land

Table 3 | Population Trend by Administrative Division

Region / State	Population (Mill. People)			Population Ratio (%)		
	1973	1983	2014	1973	1983	2014
Myanmar	28,921	35,308	51,486	100	100	100
Kachin State	738	905	1,689	2.6	2.6	3.3
Kayah State	127	168	287	0.4	0.5	0.6
Kayin State	858	1,055	1,574	3	3	3.1
Chin State	323	369	479	1.1	1	0.9
Sagaing Region	3,119	3,862	5,325	10.8	10.9	10.3
Tanintharyi Region	719	917	1,408	2.5	2.6	2.7
Bago Region	3,180	3,800	4,867	11	10.8	9.5
Magway Region	2,635	3,243	3,917	9.1	9.2	7.6
Mandalay Region	3,668	4,578	6,166	12.7	13	12
Mon State	1,314	1,680	2,054	4.5	4.8	4
Rakhine State	1,713	2,046	3,189	5.9	5.8	6.2
Yangon Region	3,189	3,966	7,361	11	11.2	14.3
Shan State	3,180	3,717	5,824	11	10.5	11.3
Ayeyawady Region	4,157	4,994	6,185	14.4	14.1	12
Nay Pyi Taw	-	-	1,160	-	-	2.3



Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016
Union of immigration and Population, 「The 2014 Myanmar Population and Housing Census」, Union of Myanmar, 2014

2) Population Density

- In 2014, the population density of Myanmar was 76 persons/㎢ and was relatively lower than that of most major Asian regions.
- Yangon represented the highest population density (716 persons/㎢), and it was followed by Mandalay (200 persons/㎢) and then by Ayeyawady (177 persons/㎢).

Table 4 | Population Density by Administrative Region

Region / State	Area (㎢)	Population Density (persons/㎢)		
		1973	1983	2014
Myanmar	676,577.23	43	52	76
Kachin State	89,041.80	8	10	19
Kayah State	11,731.51	11	14	24
Kayin State	30,382.77	28	35	52
Chin State	36,018.90	9	10	13
Sagaing Region	93,702.48	33	41	57
Tanintharyi Region	43,344.91	17	21	32
Bago Region	39,404.43	81	96	124
Magway Region	44,820.58	59	72	87
Mandalay Region	30,888.09	99	124	200
Mon State	12,296.64	107	137	167
Rakhine State	36,778.05	47	56	87
Yangon Region	10,276.71	310	387	716
Shan State	155,801.38	20	24	37
Ayeyawady Region	35,031.88	118	142	177
Nay Pyi Taw	7,057.10	-	-	164

Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016
Union of immigration and Population, 「The 2014 Myanmar Population and Housing Census」, Union of Myanmar, 2014

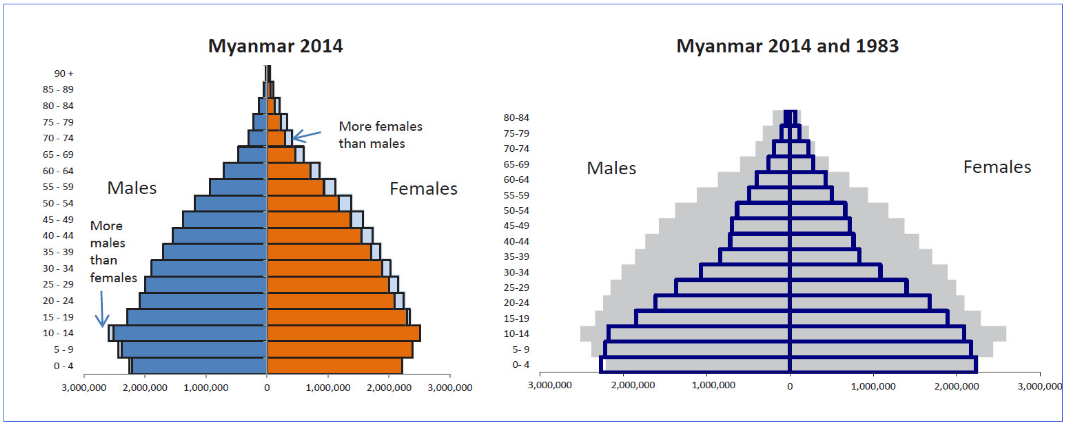
3) Population Distribution by Age

- The population pyramid by age of Myanmar is gradually changing from a pyramid shape in 1983 to a pot shape. When compared with 1983, the population has grown evenly throughout the age bands.

  - Compared with 10 years ago, the population growth rate of young generations (20s to 50s) were relatively high.
  - On the other hand, due to the reduced birth rates, improved nutrition and advanced medical technologies, the number of elderly people is growing, so the country is predicted to be an aging society in the long term.
  - Based on 2014, the senior citizens supporting rate is 52.5% in total, and the comparison with the rate of 73.9% in 1983 indicates that the population of productive age has risen drastically.

- As the layer of the elderly is thick, labor force is expected to be rich and the productive capacities are expected to be enlarged.

Figure 8 | Changes in Population Distribution by Age



Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016
Union of immigration and Population, 「The 2014 Myanmar Population and Housing Census」, Union of Myanmar, 2014

1.3.3. Economic Condition

1) Economic Condition

- According to IMF (International Monetary Fund), the GDP growth rate in 2016 of Myanmar is 6.3% or 1% down from the previous year, and the country has the highest economic growth rate among the countries in the Indochina Peninsula.

- A building project of Yangon, which had been suspended for some period, resumed from the latter half of 2016, giving its economic growth boost.

- According to IMF, the economic growth rate for 2017 is expected to be 7.5% or 1.2% up from the fiscal year of 2016.

  - After the change of government in 2015, the year 2016 saw the process of reviewing and modifying the existing government's policies. And beginning from 2017, large-scale, long-term projects are expected to be developed and implemented actively.
  - In 2017, the country is anticipated to see some policy changes such as the taking effect of a new investment law and the revision of corporation law and labor law, which are essential elements in corporate operation, thereby bringing a positive impact on the economy of Myanmar.
  - A lot of efforts are being planned to be made for the improvement of social infrastructure such as the input of development funds, revitalization of the construction market in Yangon and the continuous growth of the telecommunication industry.
  - The growth of the telecommunication and service sectors, the new government's concept for economic policies and their willingness to improve the infrastructure are prospected to work positively on the economic growth.
  - The new civilian government announced that the number of infrastructure-based projects will increase from 2017, and thus, the expansion of the transportation infrastructure and the transport demand are expected to soar in Myanmar.

Table 5 | Major Economic Indicators of Myanmar

Category	2015*	2016	2017
GDP growth rate (%)	7.3	6.3	7.5
Per capita GDP (USD)	1,148	1,269	1,375
Consumers' price index (CPI)** (%)	10.0	7.0	6.9
Export (mill. USD)	11,137	11,066	12,208
Import (mill. USD)	-16,578	-17,784	-19,721
Trade balance (mill. USD)	-5,441	-6,718	-7,513
Foreign investment (% against GDP)	7.1	5.9	6.5
Unemployment rate (%)	4	4	4

Notes: * Each fiscal year (Apr. 1 to Mar. 31 of the following year)
** CPI is based on the prices of 2012.
Source: International Monetary Fund. Asia and Pacific Dept, 「Myanmar:2016 Article IV Consultation-Press Release」, 2017

2) Budget for the Transportation Sector

a) Annual Expenditures for the Transportation Sector

• The annual expenditures of Myanmar for the transportation sector are on a gradual increase from 216 billion kyat in 2004 to 576 billion kyat in 2010, but the ratio of the transportation sector expenditures to national total expenditures decreased from 12.8% to 7.7% for the same period.

Table 6 | Expenditure & Investment Ratio Trends of the Transportation Sector

Unit : Bill. Kyat

Category	2004	2006	2008	2010
xpenditures for Transportation Sector	216	315	469	576
Expenditure Ratio for Transportation Sector	12.8%	8.5%	8.8%	7.7%

Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

b) Annual Expenditures for the Road Sector

• The budget of the MOC of Myanmar is very scarce.

- In 1996 a BOT system was introduced, and road infrastructure construction projects are planned to be carried out utilizing the budget of private companies.
- Due to the lack of road traffic, however, the revenue is not big enough to make the BOT system work, and the burden of a massive investment is very heavy.

• A comparison of the total annual expenditures of the government sector with those of the road sector indicates that about 2.9% (as of 2012) of the total government expenditures are being spent on the road sector.

Table 7 | Annual Expenditures for the Road Sector

Unit : Mill. Kyat

Year	Expenditure on maintenance (A)	Total expenditure on the road sector (B)	Government expenditure (C)	Ratio (A/B)	Ratio (B/C)
2005 ~ 2006	14,786.9	86,430.60	2,353,941	17.1%	3.7%
2006 ~ 2007	23,984.3	81,373.42	3,693,491	29.5%	2.2%
2007 ~ 2008	15,711.7	80,058.89	4,901,472	19.6%	1.6%
2008 ~ 2009	27,596.8	78,089.54	5,314,892	35.3%	1.5%
2009 ~ 2010	26,596.8	154,207.29	6,260,592	17.2%	2.5%
2010 ~ 2011	27,739.7	275,693.63	7,506,939	10.1%	3.7%
2011 ~ 2012	87,154.4	498,016.88	8,212,478	17.5%	6.1%
2012 ~ 2013	103,292.3	387,914.69	13,531,072	26.6%	2.9%
Total	326,862.8	1,641,784.94	51,774,877	19.9%	3.2%

Source: Ministry of Construction (Myanmar)

c) Revenues & Expenditures for the Rail Sector

- The revenue from the rail sector has been increasing continuously since 2008, and particularly after 2011, it tended to rise sharply. The expenditures also tended to increase gradually after 2008.

- As for the revenue and expenditures for the rail sector, expenditures have been greater than the revenue after 2008, so the accounts have been in the red every year.

Table 8 | Revenues & Expenditures for the Rail Sector

Unit: Mill. Kyat

Category		2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Revenue	Passenger	20,541	20,204	20,639	29,460	36,213
	Freight	5,468	7,689	8,288	16,734	19,623
	Other	2,104	2,210	4,237	4,803	5,844
	Sub-total	28,114	30,104	33,164	50,998	61,681
Expenditures	R/S operating cost	31,026	33,700	34,254	35,593	37,384
	Repair cost	11,191	13,634	15,988	16,394	14,669
	General operating cost	23,369	2,660	4,206	4,107	4,328
	Depreciation cost	2,781	3,689	5,177	6,651	8,946
	Total operating cost	47,368	53,685	59,626	62,745	65,329
	Management cost	3,898	3,849	5,384	6,997	15,154
	Interest cost	26	36	61	12	2,418
	Debt relief cost	(-)0.378	(-)1.483	(+)0.904	-	-
	Sales tax	1,333	1,331	1,334	1,792	1,395
	Service cost	5,258	5,216	6,781	8,801	18,968
	Expenditure total	52,627	58,901	66,408	71,547	84,297
	Profit/loss of foreign exchange	(-)8,848	(-)5,413	(-)25,223	(-)1,756	(+)5,580
Grand Total		52,618	58,895	66,382	71,545	84,303

Source: Ministry of Rail Transportation (Myanmar)

3) Gross Domestic Product (GDP)

- In 2014-15, the GDP of Myanmar was 65,437,095 million kyat, and the annual growth rate was 26.1%, which represents a gradual increase.
- As of March 2015, the biggest portion of the GDP of Myanmar was in the processing and manufacturing sector, which was followed by agriculture and trade.
- Major industries of Myanmar are primary industries such as agriculture, mining and forestry, and as the offshore development of natural gas fields was activated, the portion of the resource development sector tends to increase.
- As for the GDP growth trend of different industries, the growth rate of the electric industry is relatively higher than those of the others.

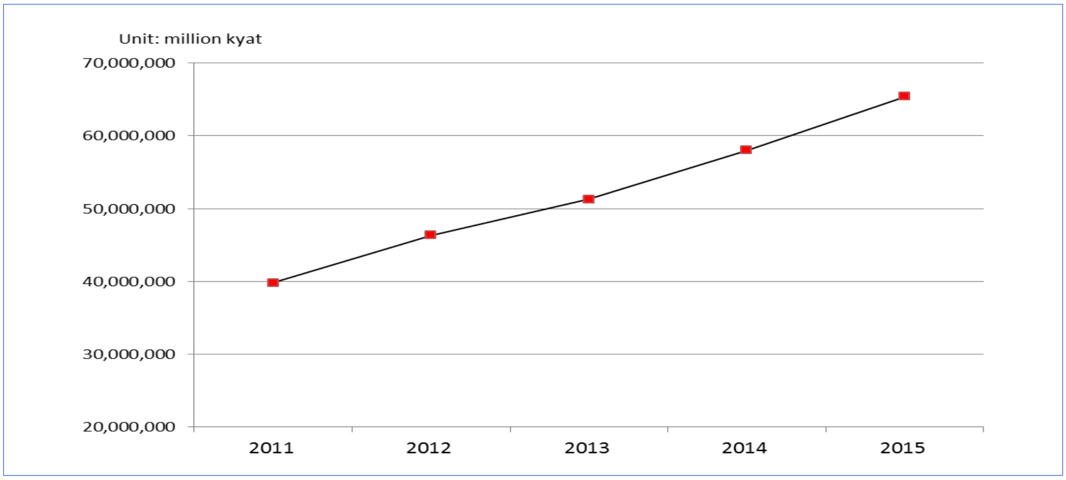
Table 9 | GDP by Industry Sector

Unit: Mill. kyat, %

Industry	2000-01	2005-06	2010-11	2011-12	2012-13	2013-14	2014-15	Growth Rate
Agriculture	1,245,437.8	4,718,474.3	11,108,404.4	11,113,043.0	11,349,615.2	12,316,081.8	12,872,823.6	18.2%
Livestock/ fishery	201,379.0	941,058.8	3,392,103.2	3,758,635.4	4,141,221.1	4,631,945.9	5,238,746.8	26.2%
Forestry	14,332.7	76,818.6	158,453.7	176,617.3	189,473.7	184,930.3	138,380.1	17.6%
Processing/ Manufacturing	182,896.6	1,572,906.7	7,900,494.0	9,132,523.0	10,299,192.0	11,553,545.4	13,043,707.7	35.6%
Electricity	3,444.4	27,652.3	421,882.7	481,449.4	614,929.5	695,854.6	924,959.1	49.1%
Construction	46,044.3	461,655.9	1,839,334.7	2,165,836.1	2,515,898.1	3,056,829.8	3,777,091.2	37.0%
Transportation	146,305.3	1,283,046.6	4,594,356.4	5,511,332.4	6,112,723.9	6,926,880.1	7,508,543.4	32.5%
Economy	2,641.1	10,237.4	37,715.4	65,318.2	85,345.7	114,385.1	135,790.5	32.5%
Trade	613,686.2	2,667,197.7	7,971,161.2	8,918,160.0	9,759,190.1	11,143,650.5	12,218,022.4	23.8%
Other	91,726.6	507,641.4	2,285,864.3	2,743,548.6	3,445,842.9	4,468,676.0	5,567,599.5	34.1%
Total	2,552,732.5	12,286,765.4	39,776,764.9	46,307,887.7	51,259,260.0	58,012,754.5	65,437,095.3	26.1%

Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

Figure 9 | Yearly GDP Trend of Myanmar



Source: Myanmar Statistical Yearbook 2015, Central Statistical Organization, 2016

- The GDP of Myanmar has been growing at more than 8% after 2011.
  - Per-capita GDP of Myanmar is about 1,270 USD in 2016, and that of South Korea is 27,633 USD. That of Myanmar is about 4.5% of that of South Korea.

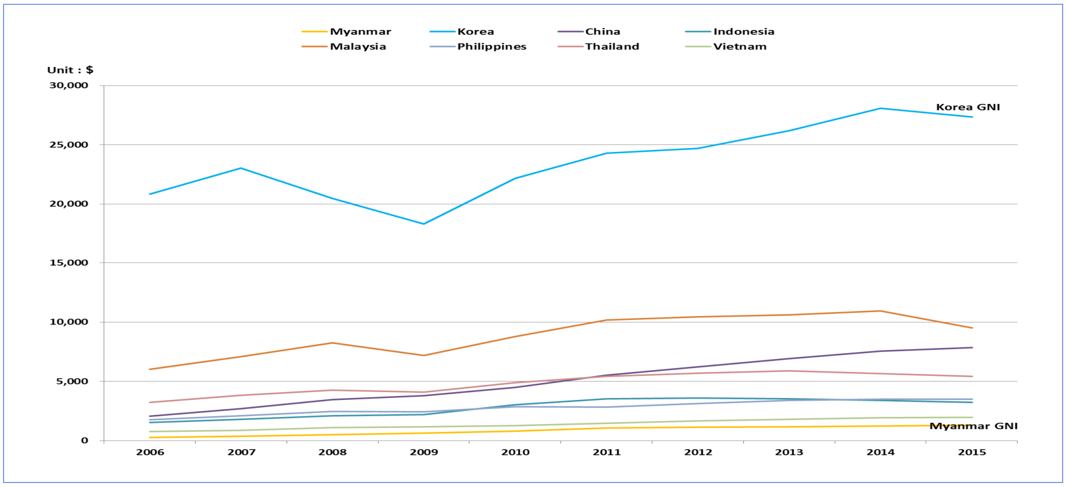
- Compared with South Korea's GDP growth of about 2.8% (in 2015), Myanmar has been rapidly growing economically.

• Over the last decade, the Gross National Income (GNI) of Myanmar has been gradually increasing from 274 USD in 2006 to 1,309 USD in 2015.

• Myanmar represents a still low level of GNI and lower growth rates when compared with major ASEAN countries.

Table 10 | Gross National Incomes (GNI) of Myanmar & Other Major Countries

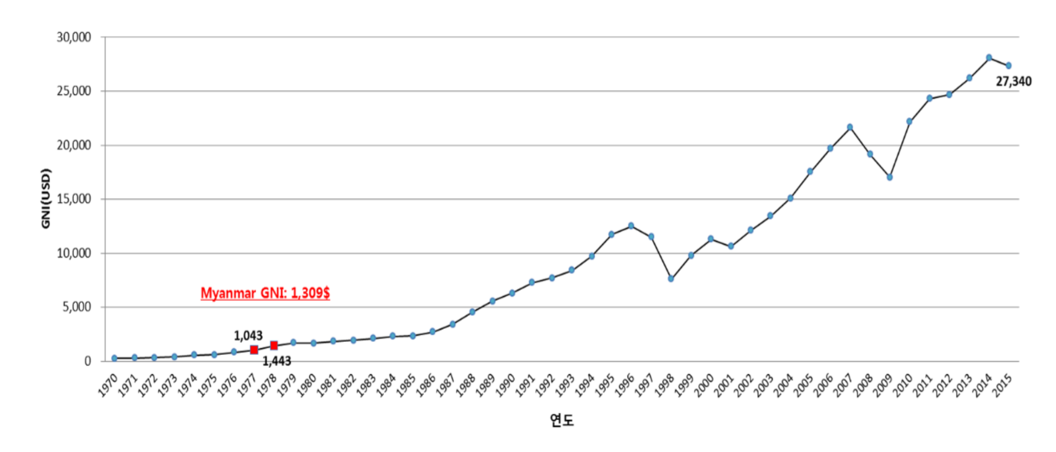
	Myanmar	South Korea	China	Indonesia	Malaysia	Philippines	Thailand	Vietnam
2006	274	20,823	2,076	1,522	6,015	1,754	3,227	764
2007	359	23,033	2,676	1,784	7,088	2,103	3,829	877
2008	505	20,463	3,457	2,091	8,233	2,443	4,243	1,111
2009	639	18,303	3,787	2,184	7,166	2,438	4,086	1,160
2010	799	22,170	4,485	3,040	8,780	2,858	4,887	1,262
2011	1,057	24,302	5,505	3,539	10,181	2,841	5,418	1,452
2012	1,126	24,696	6,228	3,593	10,435	3,139	5,676	1,656
2013	1,149	26,179	6,908	3,524	10,608	3,392	5,882	1,793
2014	1,230	28,071	7,536	3,383	10,926	3,482	5,648	1,916
2015	1,309	27,340	7,854	3,238	9,494	3,505	5,427	1,957



Sources: Statistical Office of Korea (Statistical Information Service Bureau)
The Bank of Korea「http://ecos.bok.or.kr」
IMF「International Financial Statistics」
The World Bank「http://www.worldbank.org」
UN「http://esa.un.org/unpp.」

• The per-capita national income of Myanmar is equal to the level of late 1970s of South Korea.
  - Recently, Myanmar showed a similar trend to the economic growth of South Korea in terms of its economic growth and attraction of foreign investors. Thus, the future transportation demand is also expected to rise.

Figure 10 | Per-capita National Incomes of South Korea



Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016
The Bank of Korea 「http://ecos.bok.or.kr」

4) The Number of Employees

• In 2014, the working age population of Myanmar was about 30.96 million and the unemployment rate was about 4%.

• This estimate has been obtained by applying the annual average growth rate of 3.2% for 20 years since 1990, when the survey on the employment condition was officially performed.

• The labor force of Myanmar has increased continuously with an annual increment of 600,000 people, but due to the lack of the no. of companies among others, job creation has been scarce.

Table 11 | Labor Force & Unemployment Rates

Year	Labor Force (Mill. people)			Unemployment Rate (%)		
	Men	Women	Sum	Men	Women	Sum
2000	15.02	9.28	24.30	3.60	4.74	4.03
2005	17.22	10.63	27.85	3.66	4.61	4.01
2010	19.13	11.83	30.96	3.66	4.55	4.00
2011	19.40	11.99	31.39	3.66	4.59	4.01
2012	19.66	12.16	31.82	3.66	4.58	4.01
2013	19.86	12.28	32.14	3.66	4.58	4.01
2014	13.40	8.70	22.11	3.90	4.10	4.00

Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

• The labor force is abundant as the population aged under 27 represents 50% of total population, and the labor cost is lower than that of other Southeastern countries.

– The labor cost of production workers ranges from 90 to 110 USD, which is one third of that of China and a half of that of Vietnam.

Table 12 | Comparison of Major Asian Countries' Labor Costs

Unit : USD

Country	Myanmar	Cambodia	Vietnam	Indonesia	China
Production workers' initial pay	90~110	130~160	160~200	250~300	250~350
Office workers' intial pay	200~250	220~260	250~350	350~400	450~550

Source: KOTRA, 「Strategy for Entering the Market of Myanmar 2015」, 2014

• The population that is capable of economic activity in Myanmar has been analyzed to be 67.0% of the total population. The population that is capable of economic activity in Shan State is higher than that of other cities.

• Also, the employment rates of urban areas were relatively lower than those of the countryside.

• Kayah, Sagaing, and Shan have more labor force than other cities, and are generally located in the central area of Myanmar.

Table 13 | Labor Force & Unemployment Rates by Admin. Region

State/Region	Ratios of the population that can be employed (ages 15-64)			Unemployment rate (%)			Employment rate (%)		
	Sum	Man	Woman	Sum	Man	Woman	Sum	Man	Woman
Myanmar	67.0	85.2	50.5	4.0	3.9	4.1	64.4	81.9	48.4
Kachin State	67.2	85.7	45.9	3.7	3.5	4.3	64.6	82.6	44
Kayah State	74.2	88.1	60.4	2.7	2.7	2.6	72.3	85.7	58.9
Kayin State	60.7	81.4	41.2	7.5	7.8	7.1	56.2	75.1	38.3
Chin State	64.8	77.6	53.8	5.4	5.9	4.7	61.4	73	51.3
Sagaing Region	72.3	87.5	59.1	3.6	3.4	3.9	69.7	84.5	56.8
Tanintharyi Region	64.2	86.3	42.3	4.6	4.3	5.2	61.3	82.7	40.1
Bago Region	62.4	85.4	42	5.1	4.7	5.8	59.2	81.4	39.5
Magway Region	71.3	86.8	58.5	3.3	3.1	3.6	69	84.1	56.4
Mandalay Region	67.9	85.4	52.4	3.1	3.1	3.2	65.7	82.8	50.7
Mon State	61	81.2	43	6.2	6.1	6.4	57.2	76.2	40.3
Rakhine State	58.8	83.2	38.1	10.4	9.1	12.8	52.6	75.6	33.2
Yangon Region	63.1	81.8	46.4	4.1	4.3	3.9	60.5	78.3	44.6
Shan State	77.5	88.6	66.4	2	2.1	1.9	75.9	86.8	65.1
Ayeyawady Region	63.8	85.6	43.5	3.4	3.2	3.8	61.6	82.9	41.8
Nay Pyi Taw	69.8	87.1	53.7	2.9	2.9	2.9	67.8	84.5	52.1
Urban Areas	62.6	80.5	46.8	4.8	4.9	4.7	59.6	76.4	44.6
Rural Areas	69.1	87.5	52.2	3.6	3.4	3.8	66.6	84.5	50.2

Sources: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016
Union of immigration and Population, 「The 2014 Myanmar Population and Housing Census」, Union of Myanmar, 2014

5) Trade

• From the end of 2011 when the market was opened, the import and export of Myanmar began to rapidly grow, and the trade deficits have been widened.

• In 2014/2015, the export of Myanmar was about 12.523 billion USD and the import was about 16.633 billion USD, resulting in about 4.11 billion USD in the red.

• Between April and December 2015, the export of Myanmar was 8.0653 billion USD, and the import was 12.4276 billion USD, resulting in about 4.3623 USD in the red.

• In the trade with Myanmar, the biggest partners were China, Thailand, Singapore and Japan.

• Major export partners are China, Thailand, Singapore, India, Japan, and Hong Kong, and major import partners are China, Thailand, Singapore, Thailand, Japan, Indonesia and Malaysia.

• According to the Statistical Office of Myanmar, Myanmar imported about 176 million USD from South Korea in April ~ December of the fiscal year 2015/16, and exported about 280 million USD to the same country, resulting in 104 million USD in the black.

Table 14 | Myanmar's Top 10 Export Partners

Unit: Mill. USD

Ranking	Country	2010/11	2011/12	2012/13	2013/14	2014/2015	2015.4-12
1	China	1,203.56	2,214.30	2,238.07	2,910.75	4,673.87	3,346.69
2	Thailand	2,905.18	3,823.83	4,000.57	4,306.28	4,028.69	2,302.17
3	Singapore	456.99	542.75	291.35	694.03	758.8	626.13
4	India	871.59	1,045.99	1,018.62	1,143.59	745.8	268.64
5	Japan	237.43	320.2	406.49	513.25	556.23	267.21
6	Hong Kong	34.8	16.58	26.94	489.1	288.6	266.75
7	South Korea	148.39	214.82	280.77	352.92	369.87	176.39
8	Malaysia	437.8	152.04	97.92	108.87	265.15	124.84
9	Indonesia	41.11	40.94	31.54	60.04	86.09	115.38
10	Germany	38.34	42.33	42.98	40.36	68.19	60.25
-	Other	625.92	696.93	541.75	584.81	681.6	510.85
Grand	Total	8,861.00	9,135.60	8,977.00	11,204.00	12,523.70	8,065.30

Note: The ranking is based on the outcome of April to December 2015.
Source: Central Statistical Office of Myanmar (published in Sep. 2016)

Table 15 | Myanmar's Top 10 Import Partners

Unit : Mill. USD

Ranking	Country	2010/11	2011/12	2012/13	2013/14	2014/2015	2015.4-12
1	China	2,168.52	2,786.84	2,719.47	4105.49	5019.97	5,086.32
2	Singapore	1,645.32	2,516.13	2,535.43	2910.22	4137.37	2,291.34
3	Thailand	709.09	691.15	696.81	1376.99	1678.96	1,462.49
4	Japan	256.35	502.17	1091.73	1296.24	1749.38	1,112.54
5	Indonesia	275.49	431.82	195.23	438.82	550.52	457.89
6	Malaysia	145.32	303.41	360.9	839.69	743.96	412.4
7	India	195.46	325.38	301.7	493.51	594.96	355.37
8	South Korea	304.23	451.93	343.21	1,217.98	492.99	280.2
9	Vietnam	47.05	62.29	74.72	169.86	241.15	204.83
10	USA	59.47	263.62	119.99	79.66	494.04	75.14
-	Other	606.4	700.36	629.71	831.04	929.9	689.08
Grand	Total	6,412.70	9,035.10	9,068.90	13,759.50	16,633.20	12,427.60

Note: The ranking is based on the outcome of April to December 2015.
Source: Central Statistical Office of Myanmar (published in Sep. 2016)

- The import and export items in the year 2014/2015 are as follows:

Table 16 | Myanmar's Top 10 Import/Export Items

Unit : Mill. USD

Ranking	Item	2014/15	4 to 12 2015	Item	2014/15	4 to 12 2015
-	Total export	12,523.70	8,065.30	Total import	16,633.20	12,427.60
1	Gases	5,178.60	3,426.20	Machinery & transportation means	4,944.60	4,284.70
2	Jade	1,018.00	567.9	Nonferrous metals & manufactures	1,931.60	1,382.00
3	Clothing	1,023.40	577.7	Refined mineral oil	2,447.50	1,201.70
4	Black beans (Matpe)	469.6	378.4	Electronic equipment & systems	1,037.80	1,087.20
5	Rice	651.9	410.4	Edible vegetable oils	561.5	443.9
6	Minerals	440.4	291.8	Plastic	515.5	392.6
7	Marine products & related products	306	250.3	Cement	301.4	229.5
8	Green beans (Pedessein)	368.7	228.7	Medicine & medical supplies	300.2	214.1
9	Maize	392.8	242.1	Chemical compounds	213.7	180.9
10	Pigeon peas	207.6	112.1	Scientific instruments	145.3	110.2
-	Other	2,466.70	1,579.70	Other	4,104.90	2,900.80

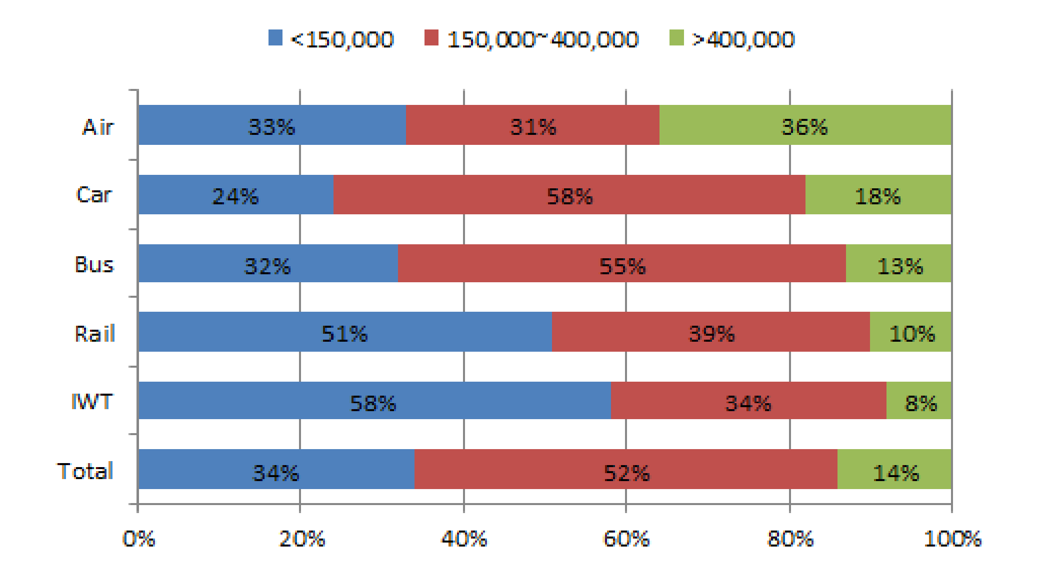
Note: The ranking is based on the amounts in October 2015.
Source: Central Statistical Office of Myanmar (CSO)

6) Income Distribution by Mode of Transportation

• In the case of the passengers of rails and IWT (Inland Water Transport), more than 50% have an income of 150,000 Kyat/month or less. Compared with other modes of transportation, their income levels are low.

• In the case of aviation, passengers with a high level of income of more than 400,000 kyat/month use the flights the most.

Figure 11 | Income Level Distribution by Mode of Transportation



Note: The unit is kyat/month.
Source: Japan International Cooperation Agency, 「The Survey Program for the National Transport Development Plan in the Republic of the Union of Myanmar」, 2014

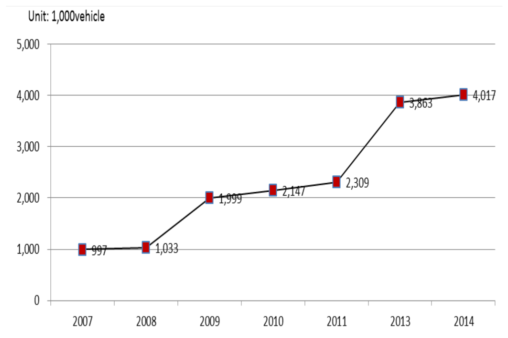
1.3.4. Numbers of Registered Vehicles

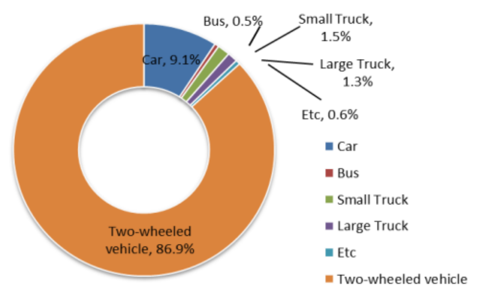
• The number of registered vehicles was about 4 million in May 2014, and it tends to increase gradually after 2007 with a growth rate of about 26.1%.

• As for the vehicle types, the number of two-wheeled vehicles was the greatest as 86.9%, and a detailed composition of vehicle types is as shown in Table 2-18.

Table 17 | Numbers of Registered Vehicles

No. of Registered Vehicles (in 2014)	Composition of Vehicle Types (in 2014)





Source: Ministry of Rail Transportation(Myanmar)

- Of major cities, Mandalay had the biggest number of registered vehicles, and the number of registered vehicles of Mandalay and Yangon amounted to 39.6% of the entire Myanmar.

Table 18 | Nos. of Registered Vehicles by State (in May 2014)

State	Car	Bus	Light Truck	Heavy Truck	Other	2-wheeled Vehicle	Total
Myanmar	359,772	21,043	60,945	49,760	21,978	3,418,918	3,932,416
Nay Pyi Taw	9,562	1,213	604	1,202	1,021	45,597	59,199
Yangon	255,406	12,126	40,666	15,169	17,310	130,997	471,674
Mandalay	55,516	2,398	8,129	14,039	1,369	1,004,995	1,086,446
Bago	4,362	520	936	3,076	733	282,238	291,865
Sagaing	6,126	1,360	2,678	3,733	307	392,415	406,619
Shan (South)	6,855	365	935	1,611	255	200,690	210,711
Shan (North)	4,111	298	2,542	2,385	204	143,054	152,594
Shan (East)	2,564	140	271	356	46	98,509	101,886
Mon	2,494	247	765	879	78	195,679	200,142
Magway	3,607	625	1,224	3,055	203	308,612	317,326
Tanintharyi	1,898	322	579	578	86	132,262	135,725
Ayeyarwaddy	1,559	937	634	1,151	261	225,859	230,401
Kachin	2,508	121	272	1,454	23	104,842	109,220
Kayin	835	87	321	433	29	72,808	74,513
Rakhine	579	141	251	239	28	26,203	27,441
Chin	211	34	23	70	5	10,633	10,976
Kayah	556	100	98	328	19	43,472	44,573

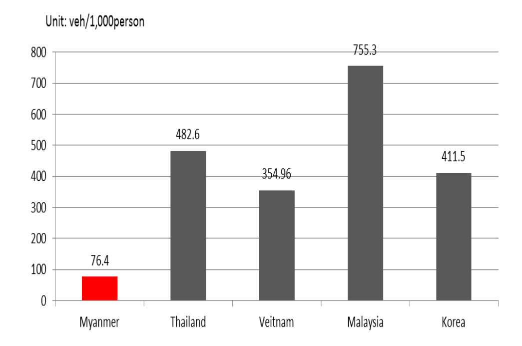
Unit : Vehicles
Source: Ministry of Rail Transportation (Myanmar)

• The country has 76.4 as the number of registered vehicles per 1,000 people, which is significantly lower than its neighboring countries.

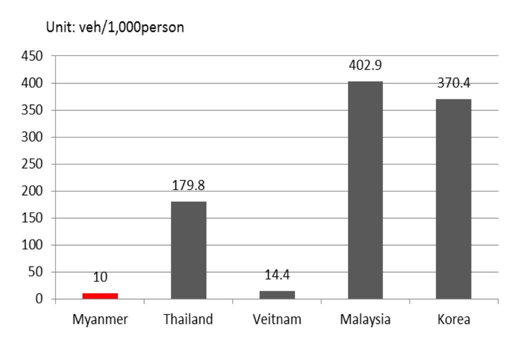
Table 19 | Comparison of the Nos. of Registered Vehicles by Nation

Item		Myanmar	Thailand	Vietnam	Malaysia	South Korea
Population (1,000)		51,486	62,828	88,773	28,334	50,948
No. of registered vehicles (1,000)	All vehicles	3,932[1)]	30,318[2)]	31,502[3)]	21,401[4)]	20,964[5)]
	Excluding motorcycles	513	11,294	1,274	11,416	18,871
No. of registered vehicles per 1,000 people	All vehicles	76.4	482.6	354.96	755.3	411.5
	Excluding motorcycles	10.0	179.8	14.4	402.9	370.4

Including two-wheeled vehicles



Excluding two-wheeled vehicles



Note: Myanmar is based on 2014 data; Thailand and South Korea are based on 2012 data; Malaysia is based on 2011 data; and Vietnam is based on 2008 data.

Sources: 1) Ministry of Rail Transportation (Myanmar)
2) http://www.thaiwebsites.com/caraccidents.asp
3) http://www.ajtpweb.org/statistics/Vietnam/road-transport-vietnam
4) Statistical Yearbook 2011 in Malaysia
5) Statistics Korea (http://kosis.kr/)

2. Present Condition of the Transportation Sector

2.1. Transportation-related Organization Structure of Myanmar

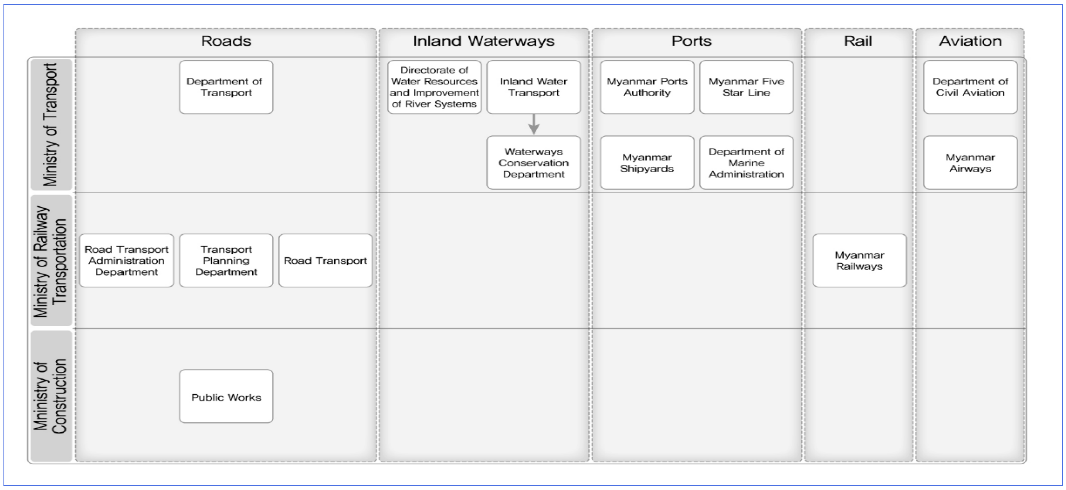
• The transport sector of Myanmar is divided into six sub-sectors such as roads, rails, inland water transport, ports, airports and urban transport.

- These transportation facilities are managed by six central ministries and city development committees, and their names are:
  - Ministry of Transport (MoT);
  - Ministry of Rail Transportation (MoRT);
  - Ministry of Construction (MoC);
  - Ministry for Progress of Border Areas and National Races and Development Affairs;
  - Ministry of Defense;
  - Ministry of Home Affairs; and
  - Yangon, Mandalay, and Naypyitaw City Development Committees.

- Of the six ministries, MoC, MoRT and MoT are major ones in charge of the operation and maintenance of the facilities concerned.

- These three ministries' organization structures and functions are as follows:

Figure 12 | Transportation-related Departments & Their Roles



Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

2.2. Roads

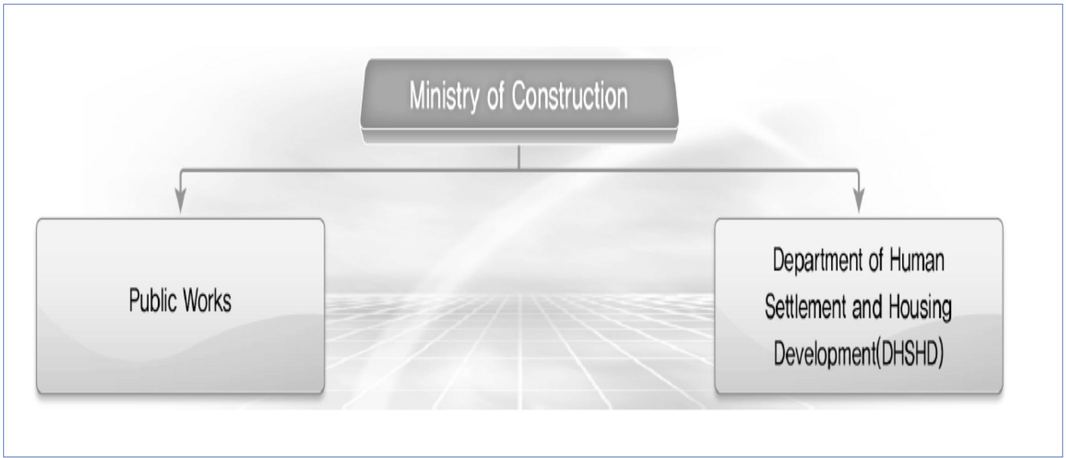
2.2.1. Road Transport-related Organizations

- Road transport-related organizations include six ministries and city development committees (Yangon, Mandalay and Naypyitaw). Of the six ministries, three (MoC, MoRT, MoT) are in charge of major parts of the entire transport network of the country.

• MoC is responsible for the construction and maintenance of roads and bridges in Myanmar and is composed of the Department of Highways, the Department of Bridge, the Department of Building and the Department of Housing and Urban Development.

- Establishment of road development policies;
- Establishment of road construction plans;
- Maintenance of roads;
- Handling and supervision of road projects jointly pursued by related departments;
- Land acquisition and permits related to road construction;
- Import of equipment for road construction and management;
- Studies related to road construction and management; and
- Detailed operation of the departments in charge of supervising public works departments and managing roads, bridges, public buildings, and airport lands.

Figure 13 | Organization Chart of the Ministry of Construction (MoC)



Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

2.2.2. Present Condition of Existing Road Networks

• The total length of roads in Myanmar is about 150,000 km, and about 45% of the entire roads are being actually used for vehicle traffic.

- Union Highways, which are a kind of trunk roads, are 19,503km in total and take up about 13% of the entire roads.

• For the road network that connects the north and the south of Myanmar, there is only one 4-lane expressway.

• The remaining roads except the expressway are 1- to 2-lane roads which are so poorly paved that they need to be improved or repaired in the long term.

• Major roads are constructed and maintained chiefly by private companies, which are collecting tolls from them through a BOT system.

Table 20 | Present Road Networks by Class in Myanmar

Road Class	Length (㎞)	Ratio (%)	Authority in Charge
Expressway	583	0.4	Ministry of Construction (MOC)
Union Highways	19,503	13.1	MOC
Regional & State roads	19,580	13.1	MOC
Major city road and other roads	27,507	18.4	City Development Committees
Village and boundary area roads	82,100	55	Ministry of Livestock, Fisheries and Rural Development
Total	149,273	100	-

Source: Ministry of Construction(Myanmar)

2.2.3. Traffic Condition

• In this project, we used the traffic survey results from the 12-hour and 24-hour surveys conducted at 393 tollgates in Myanmar under the Myanmar Trunk Road Network Master Planning Project 2015.

• The total traffic volume surveyed at 320 spots is 394,778 vehicles/day, and in Yangon Region, the biggest 120,614 vehicle/toll was surveyed, and so, one can say that the traffic volume is concentrated in Yangon Region, which is a major influence area of the project route.

• Bago, Mandalay, and NayPyiTaw, which are major influence areas of the project route, were surveyed to have 1,639 vehicle/toll, 1,338 vehicle/toll, and 933 vehicle/toll, respectively. In Yangon where the population and industries are concentrated, the biggest 6,031vehicle/toll was observed.

Table 21 | Traffic Condition by State/Region of Myanmar

State/Region	Traffic (veh/day)	Average Traffic (vehicle/toll)
Kachin	2,347	261
Kayah	604	302
Kayin	19,582	2,176
Chin	304	76
Sagaing	25,964	962
Tanintharyi	2,223	223
Bago	39,320	1,639
Magway	21,396	466
Mandalay	50,818	1,338
NayPyiTaw	3,729	933
Mon	24,798	1,550
Yangon	120,614	6,031
Rakine	1,643	75
Shan north	39,728	1,472
Shan south	14,261	793
Shan east	2,326	333
Ayeyarwady	25,121	679
Total	394,778	1,234

Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

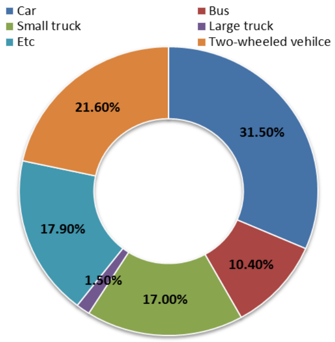
2.3.4. Composition Ratios of Different Vehicle Types

- As for the composition ratios of different vehicle types in Myanmar, cars and vans were surveyed to take up the highest 31.5% and buses were relatively low as 10.4%.

- Cars/vans and light trucks (for passengers) take up a large portion in passenger transportation, and in freight transportation, medium and heavy trucks rather than light ones take up larger portions.

Table 22 | Composition Ratios of Different Vehicle Types

Category		Composition Ratio
Car/Van		31.50%
Bus		10.40%
Truck (passenger)	Light (passenger)	17.00%
	Medium and heavy truck (passenger)	1.50%
Truck (freight)	Light (freight)	17.90%
	Medium and heavy truck (freight)	21.60%



Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

2.3.5. Vehicle Speeds

- In this project, we used the speed survey results of the Myanmar Trunk Road Network Master Planning Project by Yooshin in order to analyze the present condition of the speeds on the Yangon~Mandalay expressway, which is a possible competitor to the high-speed railway route.

- The speed survey was performed for major trunk roads of about 7,119 km, and as a result, it was found out that most roads were of one lane with poor pavement and their daily traffic was 500 vehicles/day, which is low. Except for some road sections, an average running speed of 40 km/h or below was maintained.

- As, however, the traffic volume of expressways in the sections competing with a high-speed rail is low, vehicles are running at a top speed of 100 km/h.

1) The Yangon~Mandalay Expressway

- The Yangon~Mandalay Expressway is the first expressway of Myanmar built in 2011 and currently connects major cities, and is anticipated to compete with the high-speed rail of Myanmar or the project route.
  - It is being operated with good vertical and horizontal alignments, good pavement and low traffic volumes. Most drivers are freely running under the speed limit of 100 km/h.

- In most sections, the running speed is over 90.0km/h while near the Mandalay Tollgate, the speed is 75.1km/h, which is lower than other sections, due to the operation of level crossings such as roundabouts and very small radii of horizontal curves.

Table 23 | Operating Speed Survey Results of the Yangon-Mandalay Expressway

Section		Length (km)	Travel Time (min.)	Running Speed (km/h)
Start Point	End Point			
0 Mile	115 Mile Tollgate	185.2	122	91.1
115 Mile Tollgate	Naypyitaw Tollgate	140.1	92	91.4
Naypyitaw Tollgate	Meiktila Tollgate	132.8	87	91.6
Meiktila Tollgate	Mandalay Tollgate	109	69	94.8
Mandalay Tollgate	366 Mile	22.5	18	75.1

Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

2) The Yangon~Mandalay Trunk Road

• The average running speed in this section has been investigated to be 43~45km/h.
 - As the alignment is good and the traffic volume is low, it is possible to speed up to 80 km/h in a section with a low development density, but in downtown areas with a high development density, the speed has been investigated to be 40 km/h or less.
 - As the traffic of heavy vehicles is prohibited on the Yangon ~Mandalay Expressway, such heavy vehicles as trucks and trailers are running frequently on the Yangon ~ Mandalay Trunk Road, which is the bypass road of the Expressway. (KOICA, 'Myanmar Trunk Road Network Master Planning Project,' 2015)

Table 24 | Vehicle Speed Survey Results on the Yangon-Naypyitaw-Mandalay Trunk Road

Section		Length (km)	Travel Time (min.)	Running Speed (km/h)
Start Point	End Point			
Yangon Airport	Bago	62.5	86	43.6
Bago	Taungoo	203.3	221	55.2
Taungoo	Tatkon	184.3	204	54.2
Tatkon	Meiktila	100.9	120	50.5
Meiktila	Mandalay	121.9	133	55

Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

• Although the traffic of the Yangon~Mandalay section takes up a relatively high portion of the entire traffic of Myanmar, the road networks that can be used are only the expressways and trunk roads.

• Also, there are difficulties in vehicle running due to the poor pavement condition and the high portion of heavy vehicles on existing trunk roads. Thus, if a high-speed rail is introduced into the Yangon~Mandalay section, a relatively high portion of road traffic is expected to be transferred to the high-speed rail.

2.2.6. Present Condition of Traffic Accidents

• The number of traffic accidents in Myanmar tends to increase every year.

Table 25 | Recent Record of Road Traffic Accidents

Year	No. of Accidents	Death Toll (persons)	Injured (persons)		Total Life Damages (Dead + Injured)
			Serious	Light	
2000	4,920	1,061	3,967	3,212	8,240
2005	5,755	1,283	4,899	4,721	10,903
2010	9,020	2,461	9,515	6,498	18,474
2011	10,123	2,796	7,822	9,258	19,876
2012	11,675	3,422	11,861	7,823	23,106
2013	13,912	3,721	10,642	12,736	27,099
2014	14,997	4,144	11,092	10,972	26,228

Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

• As for the traffic accident occurrence rates of different vehicle types of Myanmar, the rate of motor cycles, whose utilization rate is the highest, is the highest as about 50% and is followed by cars and trucks in order.

Table 26 | Traffic Accident Occurrence Ratios by Vehicle Type (in 2013)

No.	Vehicle Type	Ratio	Injured	Dead
1	Passenger Car	17.80%	17.70%	13.50%
2	Trucks	11.50%	10.70%	14.80%
3	Buses	6.50%	10.40%	8.60%
4	Others	1.10%	0.70%	1.30%
5	Motor Cycle	49.90%	46.40%	44.10%
6	Three Wheeler	1.80%	2.30%	1.80%
7	Trawlagyi	5.80%	7.40%	9.10%
8	Military Vehicle	0.20%	0.20%	0.20%
9	Under investigation	5.50%	4.30%	6.60%
Total		100.00%	100.00%	100.00%

Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

2.3. Rails

2.3.1. Present Condition of Rail Facilities

- The railways of Myanmar are being operated by Myanmar Railways, a state-run organization under MoRT.
- The total length of rails is 5,992㎞, which consists of 5,292㎞ single track and 700km double track, and there are 926 stations.

Figure 14 | Rail Network of Myanmar

Source: Google Images

Table 27 | Rail Facilities

Item		Size
Total Route Length		5,992 ㎞
	- Single Track	5,292 ㎞
	- Double Track	700 ㎞
Bridges		11,659 Nos
Tunnels		12 Nos.
Stations		926 Nos.
Passenger Trains		450 Nos.
Cargo Trains		21 Nos.
Locomotives		391

Source: Ministry of Transport (Myanmar)

2.3.2. Rail Transportation Condition

• Despite a vast investment on new rail lines, the importance of rails is being degraded compared with other modes of transportation.
- The freight traffic of rails in 1993 was 3 million tons, which was 30% of the entire freight traffic.
- Despite the extension of rails after 2010, it is on a gradual decrease, and the freight traffic, too, is on a decrease after 2012.

Table 28 | Recent Rail Transportation

Unit : 1,000 persons, tons

Category	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Passengers (1,000 persons)	67,650	64,221	53,816	53,208	47,883
Passenger-miles	3,328,720	3,092,709	2,365,878	2,226,815	2,122,743
Freight volume (tons)	3,408	3,580	2,839	2,467	2,280
Freight ton-miles (ton-miles)	697,848	721,863	601,906	515,010	504,758

Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

• As for the passenger traffic by station, a biggest number of passengers use the Yangon station, which is followed by metropolitan cities such as Mandalay and Myitkyina.

Table 29 | Rail Transportation by Region

Unit: Persons

Station	Getting on	Getting off	Station	Getting on	Getting off
Yangon	3,626,437	5,536,579	Lappantan	413,851	457,799
Bago	368,914	389,541	Himthads	415,662	433,817
Kyeikto	62,804	75,802	Pathain	135,475	100,696
Thahton	37,055	41,157	Kyangin	733,866	54,229
Mawlamyaing	196,107	240,909	Kyoepinkaut	68,792	73,243
Taungoo	181,081	204,877	Paungte	54,153	57,021
Pyinmana	250,935	239,981	Pyay	177,855	170,404
Naypyitaw	240,426	321,670	Myitkyina	532,430	718,117
Thazi	227,115	240,709	Kawlin	229,721	247,305
Mandalay	1,167,616	1,199,568	Naba	107,398	163,922
Pakokku	269,763	32,952	Moenyin	215,323	203,111
Bagan	178,159	142,353	Moekaung	217,255	197,938
Kyimyindine	882,196	440,548			

Source: Ministry of Rail Transportation (Myanmar)

2.3.3. Rail Operation Condition

• In Myanmar, inter-state/region passenger trains run 198 times/day, and Yangon passenger trains run 215 times/day with a daily average frequency of 413 times/day in total. Freight trains operate 32 times a day.

• The operating frequencies of passenger trains are highest in between major cities such as Yangon, Mandalay, and NayPyiTaw and the areas around them.

Table 30 | Number of Train Operation

Line	Sum	Line	Sum
Yangon-Mandalay	22	Taungtwingyi-Magway	2
Yangan-Mawlamyain-Ye-Dawei	16	Taungtwingyi-Kyaukpadaung	2
Yangon-Pyay	6	Thazi-Myingyan / Thazi-Yutsawk	2/2
Yangon-Hlelawin / Yangon-Pyay-Bagan	2/2	Taunggyi-Hsighkaung	2
Kyimyindaing-Tharawo / Lat pandan-Tharawo	2/4	Namsan-Moene	2
Mandalay-Myitkyina	14	Naba-Katha(South)-Moetagyi-Kyaukky	4
Mandalay-Lashio	2	Bago-Nyaungkhashi	4
Mandalay-Madaya	6	Pyuntaza-Madauk	2
Mandalay-Myingyan-Bagan	6	Yaychanpyin-Pyitawtha	4
Mandalay-Pakokku / Mandalay-Monywa	2/2	Kyantaung-Ponarkyun-Yoetayoke	4
Shwebo-Khin U-Monywa-Pakokku	8	Magway-Kanpya	2
Pathein-Hinthada-Kyangin-Pakokku	28	Alon-Bawditahtaung	2
Pathein-Einme	2	Pyawbwe-Ywataw-Natmauk	4
Pakokku-Gangaw-Kalay	10	Pyay-Paukkhaung	2
Naypyitaw-Bagan / Naypyitaw-Pyay	2/2	Total	198
Naypyitaw-Chauk / Naypyitaw-Mawlamyine	2/2	Yangon Circular & Suburban	215
Pyinmana-Taungtwingyi / Pyinmana-Shwenyaung	2/2	Grand Total	413
Pyinmana-Loikaw	2		

Source: Ministry of Rail Transportation (Myanmar)

- The schedule speeds of trains vary with the sections and with train types.
  - In the case of the Yangon~Mandalay Express trains, it is 35 miles/h, and in the case of mail trains, it is 31 miles/h.
  - In the case of express trains, the average speed of trains is 34.5 miles/h, which is higher than mail trains (31 miles/h) and local trains (27 miles/h).

Table 31 | Rail Operation Condition

Train Type	Line	Avg. Oper. Speed
Express	Yagon~Mandalay	35
Express	Mandaly~Yagon	34
Express	Yagon~Mandalay	35
Express	Mandaly~Yagon	34
Express	Yagon~Mandalay	35
Express	Mandaly~Yagon	34
Express	Yagon~NayPyiTaw	35
Express	NayPyiTaw~Yagon	34
Express	Yagon~NayPyiTaw	35
Express	NayPyiTaw~Yagon	34
Mail	Yagon~Mandalay	31
Mail	Mandaly~Yagon	31
Mail	Yagon~Mandalay	31
Mail	Mandaly~Yagon	31
Local (Mixed)	Yagon~Bago	27
Local (Mixed)	Bago~Yagon	27
Local (Mixed)	Thingankyun~Taungoo	27
Local (Mixed)	Taungoo~Thingankyun	27
Local (Mixed)	Taungoo~Tharsi	27
Local (Mixed)	Tharsi~Taungoo	27
Local (Mixed)	Tharsi~Mandalay	27
Local (Mixed)	Mandaly~Tharsi	27

Source: Ministry of Rail Transportation (Myanmar)

- In Myanmar, for the calculation of the rail fares, the method of being proportional to travel distance is applied, and the rail fares vary with the train type and seat class.

Table 32 | Rail Fares

Unit : Kyat/km

Train Type	Seat Class	Fare
Local	Ordinary class	5.6
	First class	7.5
	Upper class(seat)	13.0
	Upper class(compartment)	16.8
Express	Ordinary class	7.5
	First class	9.3
	Upper class(seat)	14.9
	Upper class(compartment)	20.5
Special Express(29Up)	Upper class(compartment/special)	38.7

Source: Ministry of Rail Transportation (Myanmar)

2.4. Aviation

2.4.1. Airport Facilities

- In Myanmar, 33 airports are currently being operated. Of them, three (Yangon, Mandalay, and NayPyiTaw) are international ones, and the remaining 30 are domestic ones.

- The state-run Myanmar Airways International is operating domestic flights between Yangon and other cities and international flights between Yangon and major Southeast Asian cities.

Table 33 | Present International Airports

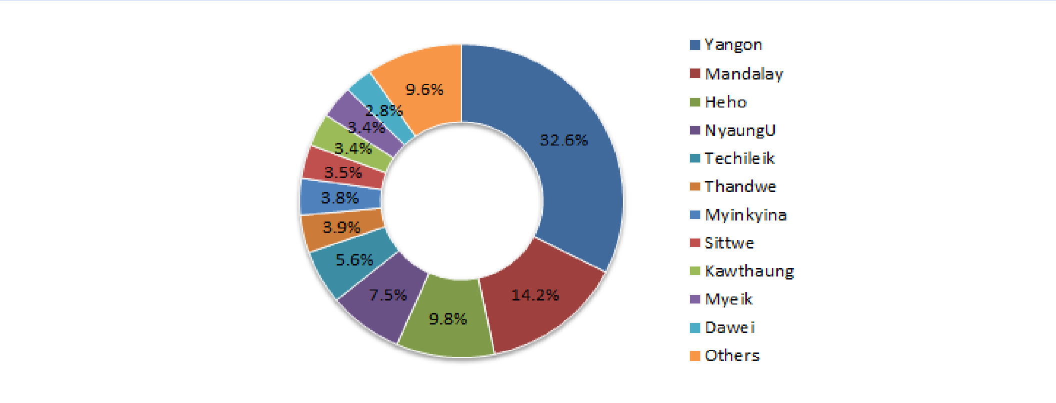
Airport	Passenger Capacity (persons)
Yangon International Airport	2.7 million
Mandalay International Airport	3.0 million
Naypyitaw International Airport	3.5 million

Source: Ministry of Transport (Myanmar)

2.4.2. Capacities of Aviation

• Domestic passenger demand shares in 2011 were biggest in Yangon and then in Mandalay, which were 32.6% and 14.2%, respectively, adding up almost to a half of the total passenger demand of the country.

Figure 15 | Passenger Demand Shares of Major Airports (2011)



Source: Department of Civil Aviation (Myanmar)

• The aviation demand in Yangon and Mandalay, which are included in the major influence areas of the project route, is likely to be transferred to the high-speed rail after its opening.

Table 34 | Passenger Traffic of Yangon International Airport

Unit: Persons

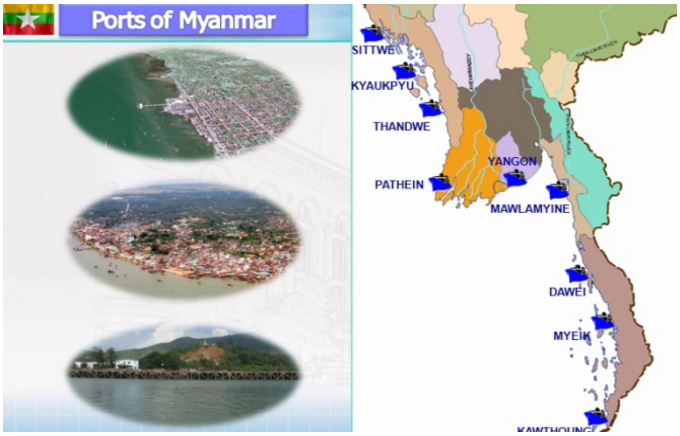
Year	No. of Passengers		Increase Rate	
	International Flights	Domestic Flights	International Flights	Domestic Flights
2003	548,202	603,774	-	-
2004	670,008	665,630	22.20%	10.20%
2005	725,858	699,209	8.30%	5.00%
2006	825,236	748,600	13.70%	7.10%
2007	867,853	755,200	5.20%	0.90%
2008	824,595	654,979	(-)5.0%	(-)13.3%
2009	967,622	659,607	17.30%	0.70%
2010	1,211,372	778,433	25.20%	18.00%
2011	1,448,729	998,616	19.60%	28.30%
2012	1,925,762	1,139,654	32.90%	14.10%

Source: Ministry of Transport (Myanmar)

2.5. Ports

• In Myanmar there are 9 ports such as Yangon, Sittwe, and Kawthaung ports.

Figure 16 | Map of Major Ports



Source: Indochina Biz Network「http://www.vinahanin.com/Myanmar/144024」

• The trade deal amounts through the ports in Myanmar continued to increase but decreased from 2014.

• Most trade activities through ports are being made in Yangon.

Table 35 | Trade Deal Amounts through Ports in Myanmar

Unit: Mill. kyat

Seaport	1995	2000	2005	2010	2011	2012	2013	2014
GRAND TOTAL	4,374.6	10,131.3	33,766.4	26,831.2	27,943.8	25,766.0	27,732.5	19,058.2
Sittwe	181.8	232.1	6,839.0	1,696.0	795.6	689.2	620.8	-
Pathein	-	20.0	-	-	0.6	-	-	-
Coco Gyun	-	-	7.4	-	1.1	-	-	-
Kyaukphyu	25.6	0.1	0.5	3.0	16.1	0.3	-	-
Myeik	595.1	408.0	4,075.4	2,484.4	1,226.2	2,459.0	1,793.3	-
Mawlamyine	25.4	270.5	1.0	-	-	0.1	-	-
Yangon	3,118.0	8,936.8	19,091.1	19,132.4	19,338.5	17,425.4	19,729.5	18,794.8
Thandwe	11.9	-	4.8	-	281.9	-	-	-
Dawei	131.6	73.9	347.1	1.6	16.0	17.5	-	-
Kawthaung	285.2	189.8	3,400.1	3,513.9	6,267.9	5,174.4	5,589.0	263.4
Maungdaw	-	-	-	-	-	-	-	-

Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

3. Rail Infrastructure & Utilization Condition Survey of Myanmar

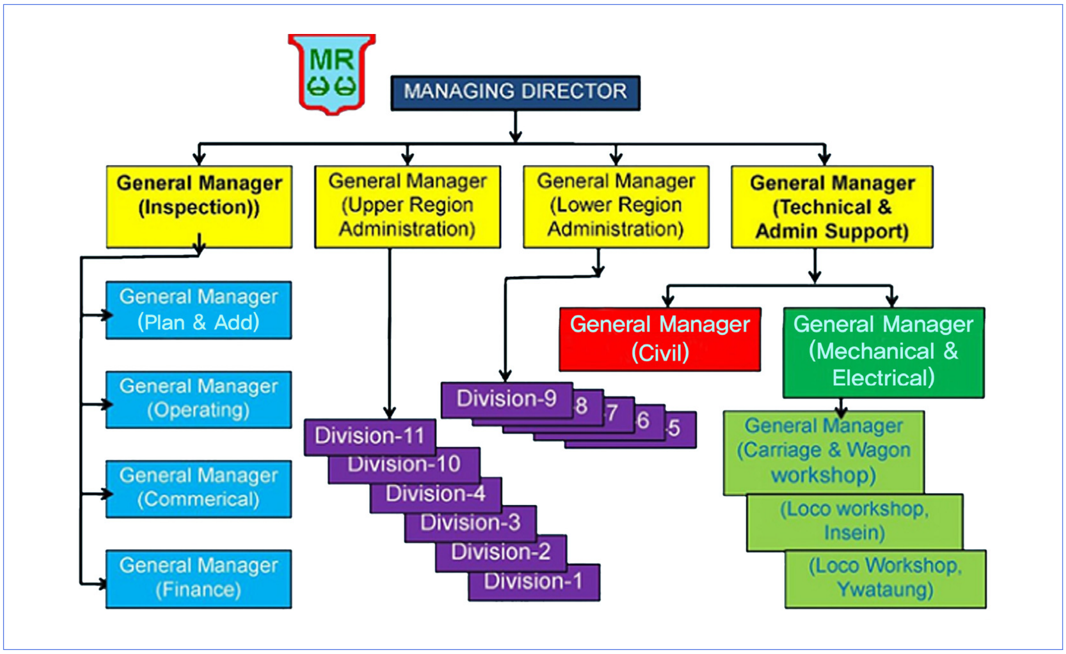
3.1. Overview

• The first railway in Myanmar was built to be 161 miles (260 km) between Yangon and Pyay in 1877.

• The track gauge is narrow (1,000 mm) and the total track length is about 3795.33 miles (6110.0km). The construction and operation of rails are managed by the MR (Myanmar Railways) under MoTC (Ministry of Transport and Communications).

• The organization of the MR has the Managing Director as its head and two General Managers. Its major departments include operation, E&M, civil, commercial, planning & administration, and finance. Under the MR, there are eleven regions and three major rolling stock depots.

Figure 17 | Organization Chart of Myanmar Railways (MR)



3.2. Infrastructure Condition

3.2.1. Track Condition

- The rail lines in Myanmar connect 13 States/Regions out of a total of 14, and their conditions are as shown in the table below.

Table 36 | Stations & Track Length by State/Region

State/Region	Area (Square miles)	No. of Stations	Route Miles
Ayeyarwaddy Region	13,567	65	260.00
Bago Region	15,214	116	461.09
Chin State	13,907	-	-
Kachin State	34,379	34	133.43
Karen State	11,731	6	16.00
Kayah State	4,538	3	8.59
Magway Region	17,305	180	754.36
Mandalay Region	14,295	183	657.43
Mon State	4,748	59	220.70
Rakhaing State	14,200	20	54.00
Sagaing Region	36,535	90	451.51
Shan State	60,155	103	501.86
Taninthayi Region	16,735	25	106.78
Yangon Region	3,927	76	169.58
Total	261,236	960	3795.33

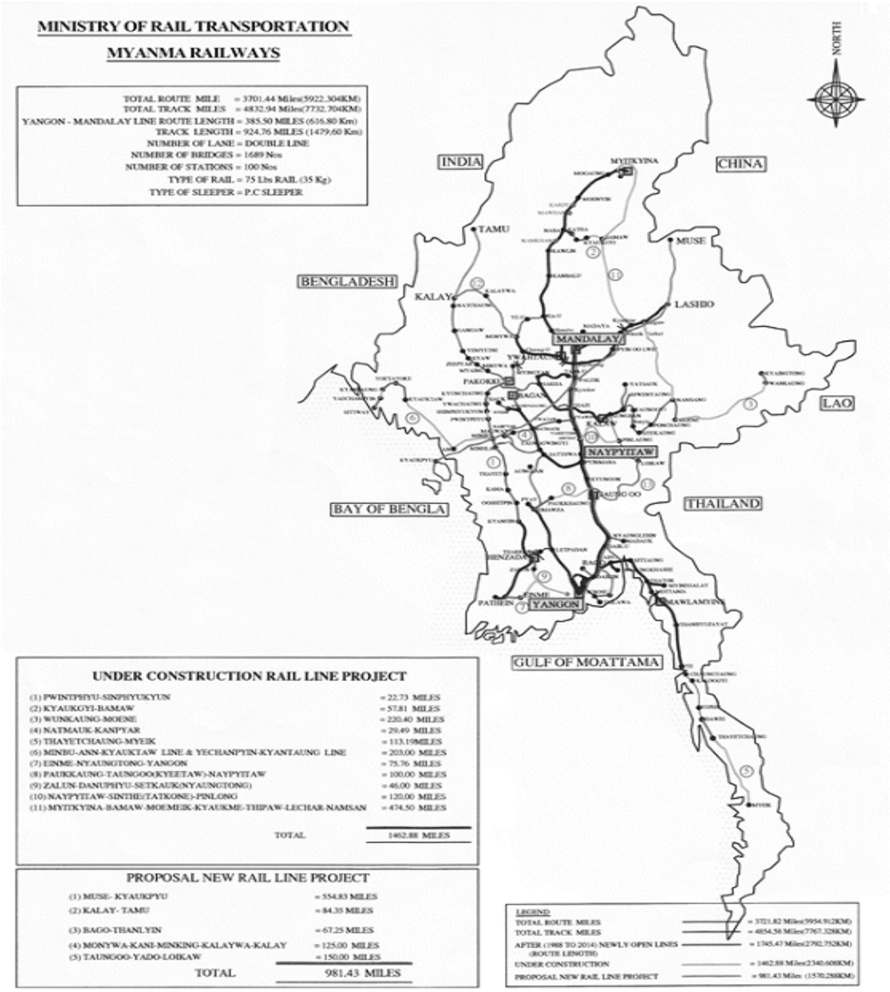
Source: MR, 'Facts about Myanmar Railways Up to December,' 2015

Table 37 | Major Arterial Rails

Line	Section	Length (miles)
Mandalay	Yangon~Mandalay	385.50
	Mandalay~Madaya	17.50
Pyay	Yangon~Pyay	161.00
	Pyay~Satthwa	90.35
Mawlamyine	Yangon~Mottama	173.00
	Thahton~Myainggale	28.15
Kachin State	Myohaung~Myitkyina	340.00
Monywa	Ywataung~Budelin ~Ye U ~Khin U	136.38
	Chaung U~Kalay	278.40
Northern Shan	Myohaung~Lashio	178.00
Southern Shan	Thazi~Lawksawk	135.50
	Shwenyaung~Taunggyi~Moenei	198.13
	Aungban~Loikaw	104.00
Myingyan	Thazi~Myingyan	69.75
	Paleik~Myingyan	68.25
	Sakha~Kyauk Padaung	64.81
Kyeeni	Pyinmana~Kyeeni	162.25
Ayeyarwaddy	Pathein~Kyangin	147.00
Mon. Tanintheryi	Mawlamyine~Ye~Dawei	192.75

Source: MR, 'Facts about Myanmar Railways Up to December,' 2015

Figure 18 | Rail Network of Myanmar



Source: Ministry of Rail Transportation

3.2.2. Roadbed & Bridge Condition

- Most roadbeds have been deteriorated without safety fencing. The facilities of level crossings are poor, making people vulnerable to safety accidents.

- In mountainous areas, slopes often fail; weak grounds continue to settle; and some areas such as Bago have been flooded. Thus, the tracks need to be improved.

• Bridges have tracks without ballast. In the case of long spans, bridges are of through truss type, and in the case of medium and short spans, deck or through plate girder type. Bridges have not been maintained well and need to be repaired and reinforced, as they show corroded girders, deteriorated concrete structures and lost piers and foundations.

• In mountainous, hilly and downtown areas, there are a lot of sharp curves and steep gradients. Also because of slope failures, vehicles' running performance is not good and the safety level of installations is low. Thus, the lines need to be upgraded with the facilities repaired and reinforced by phases.

• Major Problems of the Roadbed are as follows:

Problems in Earthworks

• Poorly maintained ballast; jaywalking; lack of safety installations such as fences → Lower operating safety and riding comfort

Problems in Bridges

• Poorly maintained tracks, corroded bridges, and lost piers and foundations → Lower structural safety

Problmes in Sharp Curves & Steep Gradients

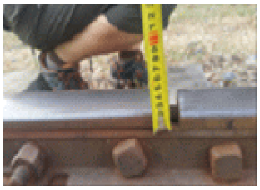
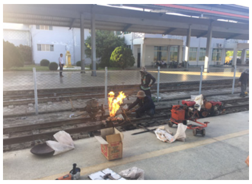
• Sharp curves & steep gradients, slope failures, and poorly managed roadbed → Lower safety and running performance

3.2.3. Trackworks

- Most of the tracks have ballast beds. On bridges, there are ballastless beds and in some stations (Yangon, Mandalay, NayPyiTaw, etc.) the yards have concrete beds.

- As the rails have not been maintained, their connecting parts are in very poor condition. As some of the gravels for ballast have been lost or buried, the tracks need to be repaired and/or reinforced.

- Chiefly in downtown areas, the rails are being elongated; the concrete beds are converted into ballast ones; and the tracks are being rehabilitated.

Lost gravels for ballast	Relaxed rail joints	Concrete beds for a station	Rails being elongated(Naypyitaw)
			

3.2.4. Stations

- The stations in major cities have relatively good passenger facilities and amenities, but the stations away from them have scanty and old amenities, which need to be upgraded.

- Mandalay Station has been upgraded into the first property with the combination of rails and civilian facilities. And Yangon and other stations are being planned to be upgraded into such ones.

- The Yangon~Mandalay section is the core corridor for the vision of a high-speed rail in Myanmar. The rail route is to be designed to be a new one, in principle, but considering the transfer to existing rails and the development of station vicinity areas, a detailed investigation has been performed for major stations, and the outcome is as follows:

Stations in Major Cities			
			
Yangon Station	Platforms	Combined Station of Mandalay	Naypyitaw Station
Medium- & Small-scale Stations			
			
Medium-scale station (Pyimana)	Small-scale station	Lack of platforms	Small-scale station platforms

Figure 19 | Yangon~Mandalay Existing Rails

Note: The inter-station distances and track lengths are based on existing rails.

Table 38 | Station Situation

Rail Station	Survey Date	Major Investigation Results	Remarks
Yangon Station (0.0km)	13 Feb. 2017	• The passenger traffic volume is the highest in Myanmar. • The platforms for the ring-type rapid transit and for conventional rails are separated. • A development plan for the station is scheduled to be established. • There is a limit to planning the HSR on a viaduct by crossing over the station (overbridge). • There are several overpasses in parallel with the viaduct. • There is no record of flood damages, but the ground level is relatively low. • The main tracks at the start and end points consist of sharp curves. • As the station plaza site is wide, it will be possible to develop an integrated station in the future.	Interviews with three people including the station master
Bago Station (74.0km)	13 Feb. 2017	• Bago and its vicinity areas are often flooded due to the overflowing Bago River (Recently in 2014, the station areas were flooded.). • The existing station is deteriorated. • The interface with other transports is not good, and a vehicular access to the station plaza is difficult. • There is a market in front of the station plaza. • The study team is considering the construction of a HSR station in Hantharwady Airport, but its construction has been suspended, and construction is under way under a new city development plan.	Interviews with two people including the station master
Phyu Station (215.9km)	13 Feb. 2017	• The station is relatively sm.all in size. • There has been no damage by floods. • Daily passenger demand of 150-200 (based on onboard passengers) • A road is in parallel with the tracks. • Markets and stores are packed around the station. • The Yangon~Naypyitaw Expressway is about 10 km away from the IC.5	Interviews with three people including the station master

Rail Station	Survey Date	Major Investigation Results	Remarks
Toungoo Station (267.1km)	16 Feb. 2017	• A foothold station between Bago and Naypyitaw. • Daily passenger demand of 500-600 (based on onboard passengers). • A major transport interfaced is motorcycles. • It is very limited to plan a HSR station as the start and end points of the station are sharp curves. • There are a lot of level crossings. • There has been no flood damage. • There is no obstacle in the site, which the study team is considering as the site for a HSR station.	Interviews with three people including the station master
Pyinmana Station (362.0km)	14 Feb. 2017	• Located in Pyinmana Township • As houses are concentrated around it, there is a high passenger demand. (this will serve as a foothold station for the whole area before the construction of Naypyitaw station). • There is no available space inside the station. • On both sides of the main tracks, there is a rail site of about 75 feet, but there are some non-permitted residential areas. • No flood damage. • The location of a HSR station needs to be reviewed in connection with Naypyitaw international airport and future urban plans.	Interviews with three people including the station master
Naypyitaw Station (373.3km)	14 Feb. 2017	• The quality of the facilities is very good as they were built recently (automatic interlocking devices are operated). • Considering the future expansion, an available land has been secured. • Daily passenger demand of 700~800 (based on onboard passengers) • For the transport interface, buses are chiefly used. • A light maintenance factory and a locomotive manufacturing factory under construction are located near the station. • The tracks in the station are in good condition.	Interviews with two people including the station master
Thazi Station (492.4km)	15 Feb. 2017	• A foothold station that connects north-south (Nawpyithaw~Mandalay) and east-west rails. • There is an available site such as the siding group inside the station. • Daily passenger demand of about 500 (based on onboard passengers)	Interviews with three people including the station master

Rail Station	Survey Date	Major Investigation Results	Remarks
Thazi Station (492.4km)	15 Feb. 2017	• The station and the main track alignments are good. • There is a level crossing near the station. • Interfaced transports include truck buses and motorcycles. • No flood damage.	Interviews with three people including the station master
Kyaukse Station (578.0km)	15 Feb. 2017	• The scale is relatively small (a population of 250,000). • There are cement, glass and shoe factories around the station. • It handles lots of freight. • There is no available space inside the station. • Daily passenger demand of about 200 (based on onboard passengers). • No flood damage. • There are a lot of level crossings around the start and end points.	Interviews with three people including the station master
Mandalay Station (620.3km)	15 Feb. 2017	• Its vicinity areas were developed for commercial purposes for the first time in Myanmar. • (The upper section of the station was developed as a hotel currently being operated.) • As it is a suspended Rahmen building, it is very limited to expand the on- and above-ground station (a tunnel station might be considered if necessary). • Daily passenger demand of about 1,000 (based on onboard passengers). • Hotels and stores are packed in front of the station. • Mandalay → Yangon (travel time 14 hours by express trains; 24 hours by slow trains) • In the aspect of the station's expandability into Kyaukse in the future, there are limits in utilizing it as a HSR station. • The study team is considering Myohaung station as a HSR station, which is currently handling chiefly freight and has a sufficiently wide site available. • There are lots of markets in front of Myohaung station. • The access road to Myohaung is very poor.	Interviews with three people including the Mandalay station master; Interviews with two people including the Myohaung station master

1) Yangon Station

View Ⅰ of Central station in Yangon

View Ⅱ of Central station in Yangon

Rapid transit platforms in Yangon station

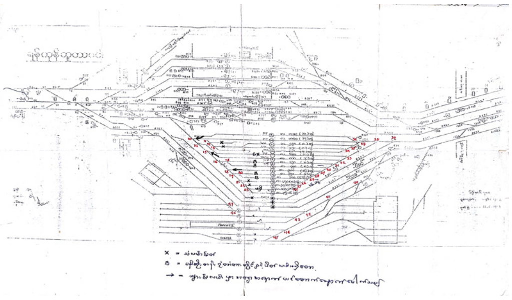
Conventional rail platforms in Yangon station

Bridge over Yangon station

Pedestrian bridge over Yangon station

Situation

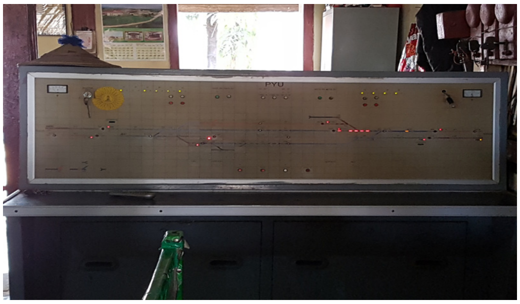
Track Layout of Yangon Station



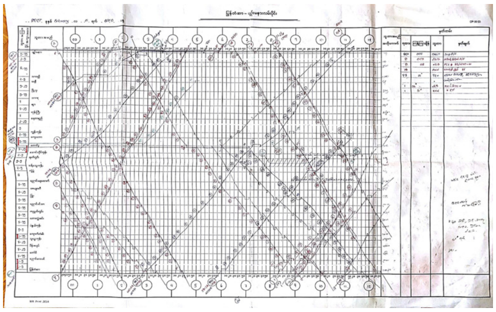
2) Bago Station

Bago station	Street in front of Bago station
	
Bago station platform Ⅰ	**Bago station platform Ⅱ**
	
Inside the station	**Inside the station**
	
Road in parallel with Hantharwady Airport	**Entrance to Hantharwady Airport (Planned to be constructed)**
	

3) Yangon Station

View I of Phyu station	View II of Phyu station
	
Inside the station (Yangon side)	Inside the station (Mandalay side)
	
Market	Road
	
Station control center	Road in front of the station
	

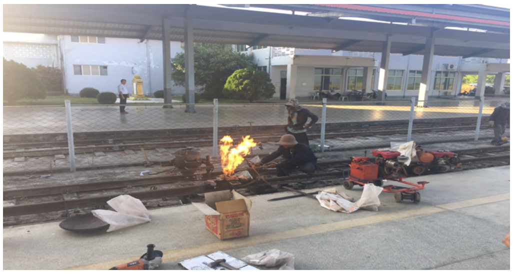
4) Yangon Station

Toungoo station	Toungoo station plaza
	
Toungoo platforms	**Toungoo station control center**
	
Inside the station	**Inside the station**
	
Integrated control center in Toungoo station	**Train operation diagram**
	

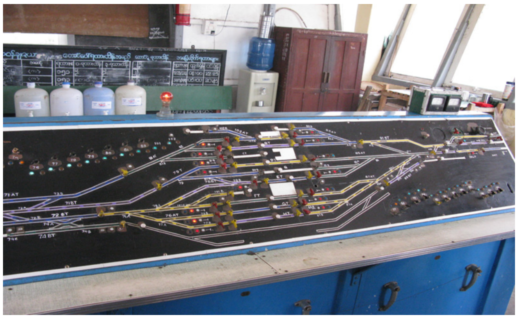
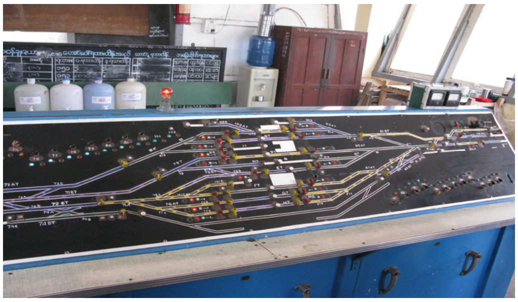
5) PYINMANA Station

Pyimana Station	Inside Pyimana station
	
Passage connected to Pyimana (overbridge)	Track and rail condition (concrete bed for main track)
	
Level crossing near Pyimana	Level crossing near Pyimana
	
Rail sides on both sides of the track (75 feet)	Level crossing near Pyimana
	

6) Nawpyithaw Station

Nawpyithaw station	Inside the station (platforms, etc.)
	
Signaling system: 3-phase	**Interfaced transport:: buses**
	
Interlocking device monitor	**Manual rail welding: Rail elongation**
	
Bus Stop	**Track Condition**
	

7) Thazi Station

Thazi station	Integrated control center in Thazi
	
Inside the station (Mandalay side)	Inside the station (Yangon side)
	
Inside the station (sidings)	Inside the station (platforms, etc.)
	
Inside the station	Integrated control center in Thazi
	

8) Kyaukse Station

Kyaukse station

Road in front of Kyaukse station

Inside the station (Mandalay side)

Inside the station (Yangon side)

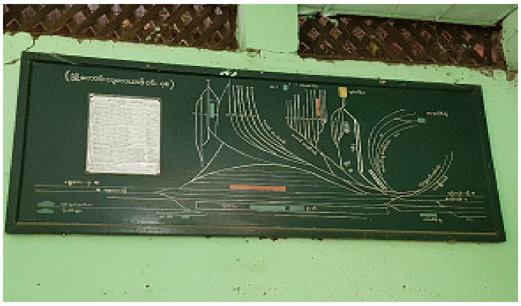
Inside the station (wagons)

Inside the station (platforms, etc.)

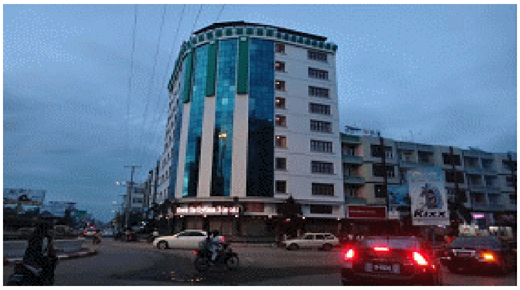
Shops around the station

Railroad crossing

9) Myo Haung Station

View Ⅰ of Myo haung station	View Ⅱ of Myo haung station
	
Inside the station (Mandalay side)	Inside the station (Yangon side)
	
Track layout	Myo haung station
	
Inside the station	Inside the station
	

10) Mandalay Station

Mandalay station	Mandalay station lobby
	
Street in front of Mandalay station	Road in front of Mandalay station
	
Inside the station (platforms; combined station)	Internal structure
	
Track layout	Shops around the station
	

3.2.5. System Condition

• The modernization of signaling and telecommunication systems have been carried out continuously, and a railway electrification plan has not been established yet.
- Yangon Ring Rail, Suburban Rail and the arterial line between Yangon and Mandalay have been being upgraded through a project of grant and loan from Japan.
- For the other sections, the upgrade is under way with the budget of MR.

• Various signaling systems are being used, and they are as follows:

(1) Computer-based interlocking color light signaling system (1 station)
(2) All relay interlocked color light signaling system (31 stations)
(3) Electric interlocked miniature lever color light signaling system (1 station)
(4) Electro mechanical interlocked color light signaling system (2stations)
(5) Automatic Block signaling system are used in Yangon Circular line
(6) Mechanical interlocked semaphore signaling system (3stations)
(7) Motorized signals with key interlocked points signaling system (semaphore arms type) (40 stations)
(8) Fixed distant working outer and home key interlocked signaling system (114 stations)
(9) Fixed distant working outer key interlocked signaling system (33 stations)
(10) Non- interlocked signaling system. (semaphore arms type) (308 stations)
(11) Military type non- interlocked Flag - Board signaling system (43 stations)

• For telecommunications, there are aerial bare lines and radio and fiber-optic systems, and among them, radio communication systems are chiefly being used.
- UHF radio transceivers: Yangon~Mandalay line
- VHF radio transceivers: Mandalay~Myitkyina line, etc.
- HF/SSB transceivers: Installed at major stations, control rooms, major construction sites, and the head office of MR.

• The train control is based on both wired and wireless systems, and the control centers for the Yangon~Mandalay and Mandalay~Myitkyina sections, which are major arterial lines, are as follows:
- Between Yangon and Mandalay
  Bago Control (From Yangon to Pyuntaza)
  Taungoo Control (From Pyuntaza to Pyinmana)
  Tharzi Control (From Pyinmana to Tharzi)
  Mandalay Control (From Tharzi to Mandalay)
- Between Mandalay and Myitkyina

- Mandalay Control (From Mandalay to Khinoo)
  Kawlin Control (From Khinoo to Nansiaung)
  Mohnyin Control (From Nansiaung to Myitkyina)

3.2.6. Rolling Stock

- The numbers of locomotives, train buses, passenger coaches and freight wagons being operated in Myanmar are as follows:

Table 39 | Numbers of Rolling Stock owned by MR

Type		Numbers	Total
Locomotive Fleet	Steam Locomotive	35	403
	Diesel Electric	244	
	Diesel Hydraulic	124	
Rail Bus Fleet	LRBE/DIB	63	288
	DMU	6	
	DRC	2	
	RBE	217	
Passenger Coaches	Upper Class	332	1,385
	Ordinary Class	776	
	Mail Vans	13	
	Brake Vans	126	
	Restaurants	26	
	Departments	82	
	Others	30	
Freight Wagons	Covered Wagon	1,140	3,395
	Open Wagon(Low Sided)	689	
	Open Wagon(Low Sided)	378	
	Timber Wagon	527	
	Tank Wagon	228	
	Brake Van	109	
	Department	79	
	Container	190	
	Others	55	

Source: Myanmar Mandalay-Myitkyina Railway Rehabilitation and Modernization Feasibility Study Final Report, Korea EXIM Bank (2016)

• The locomotives is very low in HP and have been deteriorated. Also, as their tractive power is not good enough, there are limits in maximizing the advantages of railways.

Locomotive being operated: 900~2000HP			
			
900HP- DHL,Krupp (Germany)	1500 HP -DHL,K.S.K (Japan)	2000 HP-(DEL)Dalian (China)	2000HP-(DEL)Alstom (France)

3.3. Rail Utilization Condition

3.3.1. Train Operation Condition

• MR' s daily average operating frequency of trains is 415 times: 194 times for inter-city passenger trains, 221 for suburban trains, and 24 for freight trains.

Table 40 | Train Operation Condition

Train Type		Daily Train Operating Frequency in Jan. 2015
Inter-regional passenger trains	High-speed passenger trains	40 times
	Mail and other	62 times
	Combined trainsets	64 times
	Streetcars	28 times
	Sub-total	194 times
Suburban passenger trains	Yangon suburban trains	221 times
Freight trains		24 times
Grand total		439 times

Source: MR, 'Facts about Myanmar Railways Up to December,' 2015

3.3.2. Passenger & Freight Traffic Condition

Table 41 | Passenger Traffic Condition

Unit: Million persons

Category	Years				
	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016 (until December)
No. of passengers					
Main	31.227	23.577	21.716	19.603	14.126
Suburban	32.993	30.240	31.444	28.383	20.902
Total	64.220	53.817	53.190	47.986	35.028
Persons/day	0.18	0.15	0.15	0.13	0.11
Passenger miles (100 million)	30.927	23.659	22.260	21.087	15.538

Source: MR, 'Facts about Myanmar Railways Up to December,' 2015

Table 42 | Freight Traffic Condition

Unit: Million tons

Category	Years				
	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Tonnage (million)	3.58	2.84	2.47	2.28	1.65
Tons/day (1,000)	9.83	7.78	6.77	6.33	5.41
Ton-miles (10 mill.)	72.19	60.19	51.323	50.47	38.64
Lead miles/average of freight	202	212	208	221	234

Source: MR, 'Facts about Myanmar Railways Up to December,' 2015

Table 43 | Traffic Volumes by Freight Item (Tonnage)

Unit: 1,000 tons

Item	Years				
	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Rice & rice products	97,900	113,500	84.1	54.4	28.6
Sugar cane	0.700	3.100	1.0	0.3	7.6
Forestry products	285.900	238.500	203.2	166.1	138.7
Beans	17.500	11.500	6.0	8.6	4.1
Other crops	3.400	2.200	1.1	1.7	1.2
Coal and coke	6.000	-	-	-	22.3
Oils	128.400	117.300	105.4	102.7	75.6
Mine products	21.200	26.300	22.5	17.6	6.3
Stone	119.800	193.800	76.5	153.6	130.4
Salt	47.500	31.800	10.3	28.7	27.6
Military	56.100	48.900	62.0	59.7	60.9
General products	744.600	581.000	519.9	507.6	370.4
Parcels inside the region	966.000	806.500	849.0	663.0	408.3
Other parcels	1,112.000	661.600	526.0	516.0	374.0
Total	3,580.000	2,836.000	2,467.0	2,280.0	1,656.0

Source: MR, 'Facts about Myanmar Railways Up to December,' 2015

4. Yangon~Mandalay Travel Pattern Analysis

4.1. Rail Transportation Condition

4.1.1. Rail Transportation Condition of Myanmar

1) General

- Although Myanmar has a vast land, its road and rail facilities are retarded, not meeting the demand of logistics.

- Despite the extension of rails after 2010, it is on a gradual decrease, and the traffic volume of freight is also on the decrease after 2012.

Table 44 | Rail Transportation Condition

Unit: 1,000 persons, tons

Category	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
No. of passengers (1,000 persons)	67,650	64,221	53,816	53,208	47,883
Passenger-miles	3,328,720	3,092,709	2,365,878	2,226,815	2,122,743
Freight volume (tons)	3,408	3,580	2,839	2,467	2,280
Freight ton-miles (Ton-miles)	697,848	721,863	601,906	515,010	504,758

Source: Central Statistical Organization, 「Myanmar Statistical Yearbook 2015」, 2016

11) Transport Shares

- The year 2013 daily passenger travel demand in Myanmar in terms of inter-zonal movement is summarized as follows:
  - Total trip generation: approximately 300 thousand trips per day
  - Total passenger kilometres: 102 million passenger kilometres per day
  - Average travel distance: 340 kilometres per person for a continuous travel

- In terms of modal share, bus transportation is dominant, reaching at about 53% of the total,

- followed by car 23%, railway 18%, IWT 3% and Air 2%. Figure 8.2 illustrates modal share by travel distance.

Table 45 | Observed Current Passenger Movement in Myanmar

Transportation Mode	Inter-zonal Trips (Trips / day)	Modal Share (%)	Passenger* km (thousand)	Average Distance (km/Trips)
Air	7,282	2	4,559	626
Car	68,414	23	14,479	212
Bus	160,042	53	62,689	392
Rail	55,286	18	16,985	307
IWT	9,421	3	3,470	368
Total	300,445	100	102,182	340

Source: Japan International Cooperation Agency, 「The Survey Program for the National Transport Development Plan in the Republic of the Union of Myanmar」, 2014

4.1.2. Rail Transportation Condition in the Project Route (Yangon~Mandalay)

- In 2012, the rail traffic in the Yangon~Mandalay section was about 7 million/year (23,000/day).

- The Yangon~Mandalay section is experiencing a gradual decrease in traffic volume, which is similar to the entire rail traffic of Myanmar.
  - In 2011 and 2012, the annual average variance was about -3.3%, which represents a continuous decrease.

- Of rail types, express rails had the highest share as about 65% of total. And in the Yangon~Bago section, the boarding (getting on the train) and deboarding (getting off the train) traffic volumes were the highest.

Table 46 | Rail Transportation Condition of the Project Route (Yangon~Mandalay)

Unit: Trips/mon.

Type	March 2012	April	May	June	July
Express	260,244	275,331	249,308	197,196	188,032
Mail	37,972	39,912	36,300	32,180	33,430
Local	54,715	45,478	53,528	48,703	48,505
LRBE	47,820	40,722	45,948	42,051	42,803
Total	400,851	401,443	385,084	320,130	312,770

Source: Ministry of Rail Transportation (Myanmar)

4.2. Road Transportation Condition

4.2.1. Traffic Condition of the Yangon~Mandalay Section

- In the Yangon~Mandalay section, Yangon has the highest average traffic volume as 6,031vehicle/toll, and is followed by Bago with an average traffic volume of 1,639 vehicles/toll.

Table 47 | Traffic Conditions by State/Region of Myanmar

State/Region	Traffic Volume (veh/day)	Average Traffic Volume (vehicle/toll)
Bago	39,320	1,639
Mandalay	50,818	1,338
NayPyiTaw	3,729	933
Yangon	120,614	6,031

Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project, KOICA」, 2015

4.2.2. Present Condition of the Yangon~Mandalay Road Network

1) The Yangon~Mandalay Expressway

- The Yangon~Mandalay Expressway, which is a rival to the project route, is the only expressway in the country that connects Yangon and Mandalay with a total length of 586.7 km.

- The average running speed of the Yangon~Mandalay Expressway is 91.18 km/h, and is relatively higher than that of the Yangon~Mandalay Trunk Road (52.85km/h).

- The speed limit on expressways is 100 km/h, and trucks are prohibited from using them.
  - Total length: 586.7km
  - No. of lanes: 3 lanes of one way (2 lanes of one way in some sections)
  - Average running speed: 91.18 km/h
  - Speed limit: 100 km/h
  - Toll: 4,500 Kyat (for cars), 22,500 Kyat (for buses)
  - Note: Trucks are prohibited from accessing expressways.

4.3. Traffic Volume Distribution Pattern Analysis

- In this project, the patterns of traffic distribution in Myanmar have been analyzed using the O/D data established by existing studies (KOICA, 2015).

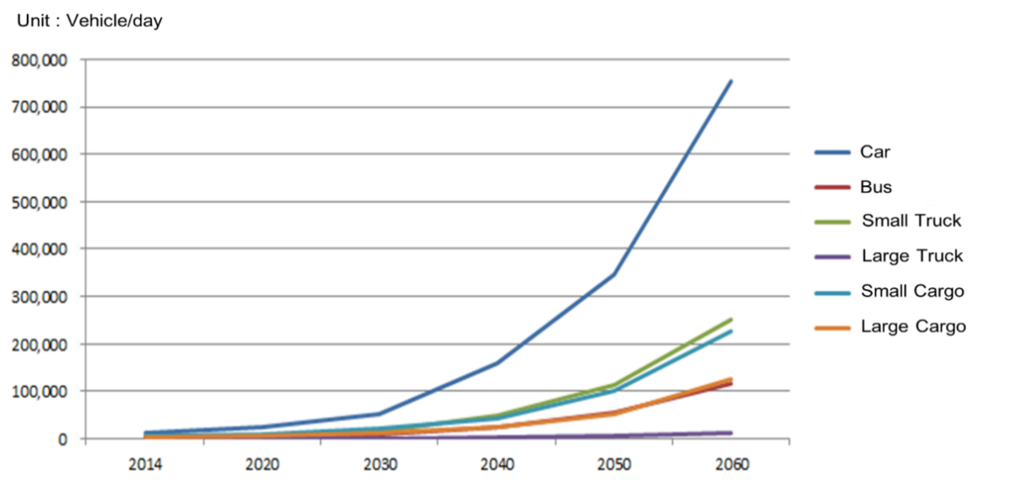
- As a result of the analysis of the existing data, the total traffic volume of Myanmar tends to rise gradually after 2014 with an annual average growth rate of 9.3%.
  - In general, the transportation means that use the roads are on the increase, and particularly, the annual average growth rate of buses was the highest as 9.8%.

- As a result of analyzing the total traffic patterns around the project route except for rails, it has turned out that the modal share of cars is the highest as about 50%.

Table 48 | Traffic Distribution around the Yangon~Mandalay Section

Unit: Vehicles/day; %

	2014		2020		2030		2040		2050		2060	
	Traffic	Share	Traffic	Share	Traffic	Share	Traffic	Share	Traffic	Share	Traffic	Share
Sum	26,739		47,043		106,797		302,511		670,586		1,486,904	
Car	12,623	47.2	22,776	48.4	51,071	47.8	157,665	52.1	344,698	51.4	753,601	50.7
Bus	1,760	6.6	3,273	7.0	7,882	7.4	23,459	7.8	56,098	8.4	117,257	7.9
Mini Bus	3,530	13.2	6,409	13.6	15,057	14.1	50,028	16.5	111,847	16.7	250,056	16.8
Large Bus	336	1.3	545	1.2	1,085	1.0	2,567	0.8	5,740	0.9	12,833	0.9
Light Truck	5,402	20.2	8,740	18.6	19,949	18.7	43,648	14.4	99,756	14.9	227,992	15.3
Heavy Truck	3,087	11.5	5,301	11.3	11,752	11.0	25,143	8.3	52,447	7.8	125,165	8.4

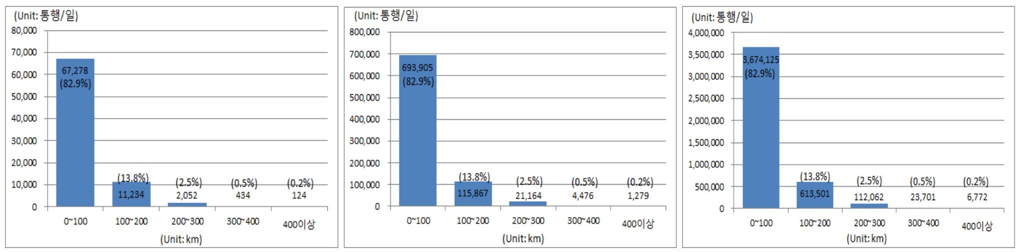


Source: Network & O/D by Modes of Transportation of Myanmar

Table 49 | Average Onboard Passengers of Myanmar

Unit : Persons/vehicle

State/Region	Car	Bus	Light Truck	Medium & Heavy Truck
Kachin	4.07	33.8	11.21	17.66
Kayah	7.97	31.86	13.68	22.33
Kayin	3.35	33.83	9.4	9.67
Chin	4.34	21.72	10.59	12.09
Sagaing	3.71	28	8.78	12.31
Tanintharyi	4.42	28.42	11.34	19.74
Bago	3.74	30.34	12.01	13.64
Magway	4.29	23.97	11.04	20.65
Mandalay	3.9	23.28	11.55	13.35
NayPyiTaw	3.06	28.52	11.22	19.1
Mon	3.53	38.23	10.07	10.58
Rakine	3.06	29	11.09	23.97
Yangon	3.24	30.9	14.82	15.13
Shane	4.22	22.22	9.75	17.12
Ayeyawaddy	4.76	32.94	11.1	16.47
Total	3.66	28.9	12.08	15.5



5. Rail-related Policy & Development Plans of Myanmar

5.1. National development program

5.1.1. National Comprehensive Development Plan (NCDP)

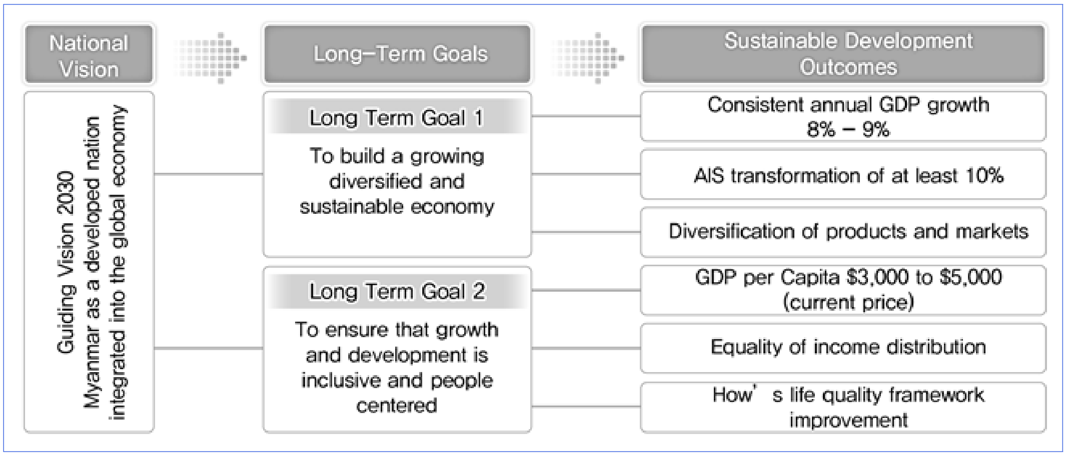
• The NCDP is a national development plan with the goal of leading all types of development and reform, especially in economic, social, cultural, and environmental areas. It is a 20-year plan carried out in five-year periods, with the first five-year plan (2011-2016) currently underway. The vision and goals of the NCDP are as follows:

Figure 20 | Vision & Goals of NCDP

Source: KOICA, 'Myanmar Monywa~Gangaw Road Upgrade Project FS,' 2015

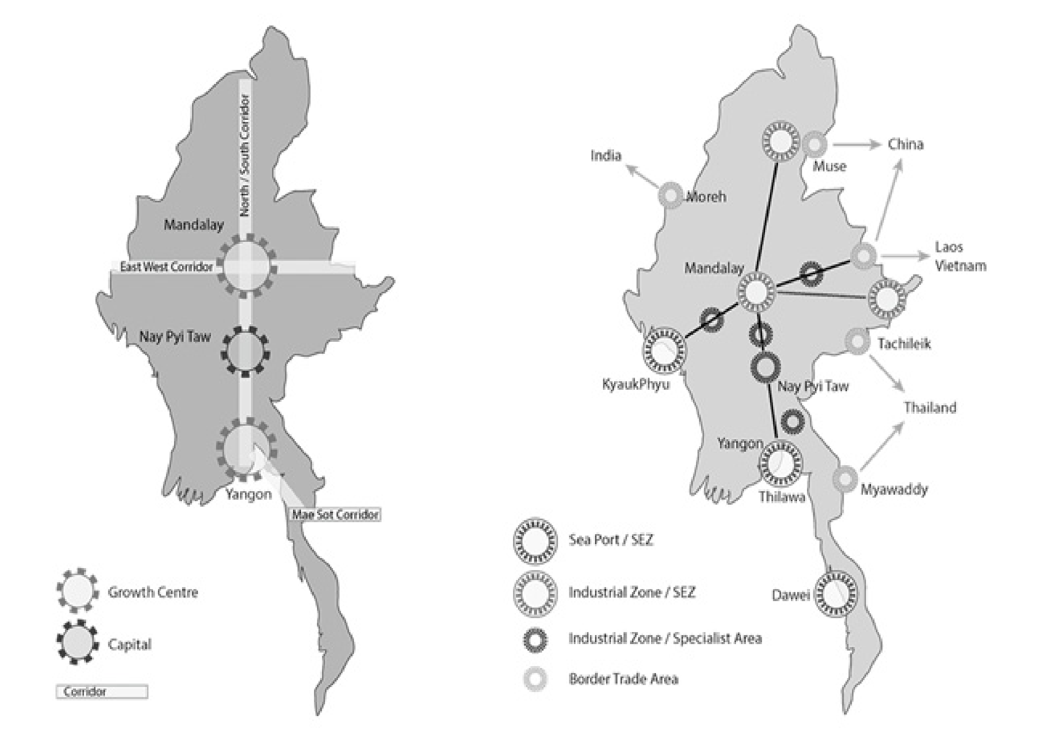
- In accordance with the NCDP, the government of Myanmar has established national development goals to achieve sustainable economic performance, such as continuous GDP growth, diversification of products and markets, and distribution of national income.

Figure 21 | Vision & Goals of NCDP



• The development concept adopted by the NCDP to achieve efficient and balanced economic growth involves designating Yangon and Mandalay as "growth poles" and developing the North-South corridor and East-West corridor, with Mandalay at the center. Moreh, Muse, Tachileik, and Myawaddy will be designated as border trade areas in order to promote trade and industrial activities in those areas. Furthermore, it will enhance connectivity between the country's SEZs, such as those in Kyaukphyu, Thilawa, and Dawei, and neighboring countries, including China, Thailand, Cambodia, Vietnam, and Laos. Source: KOICA, 'Myanmar Monywa~Gangaw Road Upgrade Project FS,' 2015

Figure 22 | Growth Pole+Growth Center Strategy



Source: KOICA, 'Myanmar Monywa~Gangaw Road Upgrade Project FS,' 2015

5.1.2. National Transport Development Plan (NTDP)

• The JICA report summarized the key objectives and policies of relevant ministries and agencies with an interest in land development based on employment and economic activities (agriculture, manufacturing-industries, Industrial Zones, SEZs, and tourism), as well as the environment.
- NTDP's Vision for Transportation and Road Sectors is as follows:

Table 50 | Vision for Transportation

• To develop an efficient, modernized, safe, and environmentally-friendly transportation system in a coordinated and sustainable manner that embraces all transport modes for the benefit of the country and the people of Myanmar

Table 51 | Vision for Road Sector

• Develop all-weather and safer road transportation infrastructure in order to fulfill the social and economic transportation needs of the nation in a coordinated manner with other modes of transport • Build a robust foundation for land transportation industries, in terms of road infrastructure and regulatory framework • Achieve environment-friendly development of a land transportation system throughout the country

Source: The 6th Joint Coordination Committee Meeting, MYT-Plan, JICA, March 2014

- According to the NSDF, the cities and regions of Myanmar were classified according to a four-level hierarchy.

- At the primary level, the country's major cities--Yangon, Mandalay, and Naypyitaw--are designated as "National Centers." These cities have large populations, high economic activities, and existing transportation investment, and werer designated for future investment in projects to increase the capacity of their highways, railways, ports, and airports.

- At the secondary level are the "Regional Centers," which include clusters of commercial and industrial activities that have major transportation nodes and are well connected to highways, railways, and rivers.

- At the tertiary level are "Agro-Industry Centers," which include regional cities that have well-developed agricultural industries and also those regional economies that are substantially based on the agriculture sector.

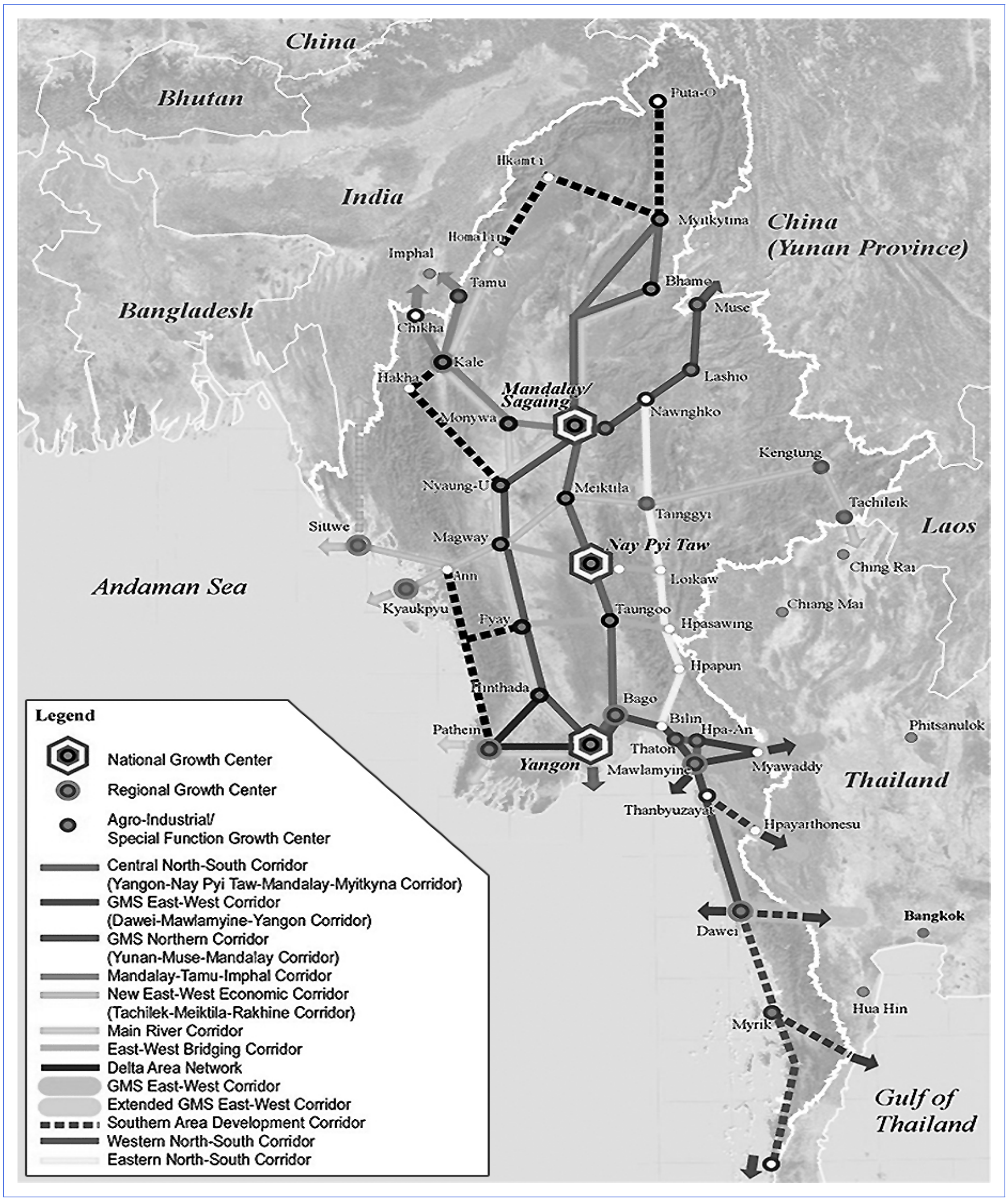
- Finally, at the lowest level of the hierarchy are "Special Function Center Border Towns/Port Activity Hubs," which are located on the borders with neighboring countries and possess geographical advantages and major ports. As defined by the NSDF, these classifications and major functions are shown in following table. Source: KOICA, ‘Myanmar Monywa~Gangaw Road Upgrade Project FS,’ 2015

Table 52 | Function of city

Type of Center	Functions	Cities	
National Growth Centre	• Capital City: Major State/Regional Capitals, Govt. institutions • Major and Specialized CBDs and Industrial Zones • National Universities and Research Centers • National/State Hospitals/Specialized Hospitals • National/City Parks and Tourism/Heritage Sites • International Airports, Major Ports	Naypyitaw Yangon Mandalay/Sagaing	
Regional Growth Centre	• State/Region Capitals, Regional Govt. Administrations • Main Commercial and Agro-Industrial Clusters • College/Vocational Training, Secondary Hospitals • Main Post Offices, Municipal Libraries, Main Emergency Services • Regional/Municipal Parks and Tourism/Heritage Sites • Regional Airports, Ports	Myitkyina Sittwe Kyaukphyu Pathein Bago(Hanthawaddy) Mawlamyine Dawei	
Agro-Industrial Centre	• District/Township-level Govt. Administrations • Agriculture/Agro-Industry with some Commerce • Secondary Schools and Hospitals • District Port Offices, Town Libraries, Emergency Services • City/Town Parks and Specialized Tourism/Heritage Sites • Airports, Ports, or nearby areas	Lashio Shwebo Kale Monywa Meiktila Taunggyi	Taungoo Magway Pyay Hinthada Thaton Hpa-an
Special Function Growth Centre	• Cross-Border or Port Trading Activities • Local Schools and Primary Healthcare Facilities • Local Post Offices, Specialized Emergency Services • Limited Local Parks, Tourism Sites • Specialized Parks, Airports with • Security/Administration Functions	Muse Tamu Nyaung-U Kengtung	Tachileik Myawaddy Myeik

Source: Adoption of the Myanmar National Transport Development Plan, JICA, April 2013

Figure 23 | Conceptual Diagram of National Spatial Framework (NTDP)



5.2. Rail-related Plans

5.2.1. Yangon-Mandalay Rail Upgrade Project (ODA Loan of Japan)

- The Yangon-Mandalay rail length is about 386 miles, and the project is to be implemented in three phases:
  - Phase 1: Yangon~Toungoo 166 miles
  - Phase 2: Toungoo-Yamethin 108.5 miles
  - Phase 3: Yamethin-Mandalay 111 miles

- The project scope includes the upgrading of roadbed and rail tracks, reconstruction and/or replacement of bridges and relevant civil structures, installation of new signaling and telecommunication systems or upgrading of the existing systems, introduction of new rolling stock and rehabilitation and installation of cargo facilities.

- The Exchange Note and the Loan Agreement were signed on 5 Sep. 2015, and 20 billion Yen were provided for Phase 1.

- Phase 2 is going to be completed in September 2022. After the completion of the entire project, the travel time by Yangon-Mandalay express passenger train is expected be reduced to less than 8 hours.

5.2.2. Signaling & Telecommunication System Upgrading Plan (2015~2025)

- Yangon ring and suburban lines and the Yangon-Mandalay arterial line are being pursued as a donation and loan project by Japan.
  - New signaling systems to be installed at: Yangon and Pazundaug stations
  - Installation of automatic gate barrier systems between Togyaunggale and Ywathagyi (Kyansitthar level crossing)
  - In the Yangon-Pyuntaza section, a train operation control center (OCC) and a centralized train monitoring system (TMS) are to be installed.
  - Upgrading of signaling and telecommunication systems between Yangon and Mandalay
  - Upgrading of signaling and telecommunication systems for the Yangon ring line

- For other sections, too, the military-type signaling systems are being upgraded to semaphore arms with the MR’s budget.

5.2.3. International Rail Connection Plans & Medium- & Long-term Rail Upgrading Plans

1) Myanmar-Thailand

- In 2005~2007, a feasibility study was conducted on the rail connection being planned for Three Pagoda Pass (Mynmar)~Namtok (Thailand) as a branch line of the Singapore - Kunming rail project (SKRL).

- A rail connection between Dawei (Myanmar) and Kanchanaburi (Thailand) was discussed instead of the existing line in the 14th special working group meeting on the Singapore-Kunming rail project held in Vientiane, Laos, in 2012. But after that, there hasn't been project implementation.

2) Myanmar-China

- For the Muse-Kyaukphu rail transport system, a Memorandum of Understanding was signed in 2011 between a Chinese rail engineering company (CREC) and the MR of Myanmar.

- The project route is 808.8 km long from Rulei of China to Muse, Lashio, Mandalay, Magwe, Minbu, Ann and to Kyaukpyu of Myanmar (total length is 4.2 km in China and 808.8 km in Myanmar). In April 2012, a feasibility study report was written.

3) Myanmar-India

- The Kalay-Tamu line (135km in Myanmar) was not determined to be economically viable as a result of the feasibility study in 2004.

- As a result of the discussions regarding the rail connection between the two countries in NayPyitaw on 16-17 January 2013, both parties agreed to cooperate with each other when writing a detailed report on rail construction projects.

Ⅲ. Case Studies on the Introduction & Operation of the High-speed Rails of Korea

- In the analysis of model cases of introducing and operating the high-speed rail of Korea, the present condition of the currently-operated rail industry of the country will be analyzed together with the rail history developed with the industrialization under the country's 5-year economic development plans, and by doing so, implications will be drawn that will be utilized for the establishment of rail policies for Myanmar.

- As regards the rail history of Korea, the focus will be put on the cases of the introduction and operation of the KTX whose service was opened in 2004 and the transformation from diesel trains to electrified trains ("the electrification project") between the latter half of 1960s and 1970s.

- By analyzing the background, process and procedure, issues and challenges of the rail electrification and the introduction of KTX, what supports will be needed for the government of Myanmar's introduction of a high-speed rail will be figured out, and the effect of rail construction will be provided through an analysis of project effects.

1. Overview of Korea's Rail Industry

1.1. Korean National Railroads' Organization Structure

1.1.1. Restructuring of Korean National Railroads

1) The Need to Restructure Korea's Rail Industry

- Korea founded the state-run Korean National Railroads (Korail) in 1963, thereby managing and operating railways under the direct control of the government.

• But the 5-year economic development plans initiated in 1960s were implemented focusing on the road transport. With the opening of the Gyeongbu (Seoul-Busan) Expressway in 1970, a continuous investment was made on the roads, resulting in a decreased competitiveness of rails and the operating deficits of the rail business.

- Due to the annual operating deficits of tens of millions of Korean Won (“KRW”), the quality of rail services was degraded, and it led to a lower competitiveness of rails, resulting in operating deficits. And these vicious cycles were repeated.
- Such operating deficits were made up by the taxes collected from the people of Korea, aggravating their burden.

• As the deficit operation of rails continued to occur after 1976, the government began to discuss ways of improving the rail management from the latter half of 1980s.

• The government tried to improve the rail management condition within the frame of its direct control rather than by restructuring the rail industry by enacting a law covering special cases on the state-owned railways in 1996 (“the Special Rail Law”) and taking other measures, but the operating deficit of rails worsened.

- The government secured Korail’s governance autonomy by enacting the Special Rail Law and proceeded with management improvement by curtailing the manpower of about 7,000, but the management situation became even worse as the operating cost increased at an annual growth rate of 4.8% while the operating revenue increased only at an annual growth rate of 1.8%.

Table 53 | Korail’s Operating Account after the Enactment of the Special Rail Law

Unit : 100 Mill. KRW

Item	1996	1997	1998	1999	2000	2001	2002
Operating income	13,822	14,642	13,662	14,025	14,575	15,270	15,366
Operating cost	17,828	19,534	19,937	19,493	21,053	22,350	23,645
Operating balance	-4,006	-4,892	-6,275	-5,468	-6,478	-7,080	-8,279

Source: MoCT of Korea, 「Rail Industry Restructuring」, 2003

• As it failed in the management improvement under its direct control, the government analyzed the fundamental problems of the rail management, and to solve them, it devised a rail industry restructuring plan in 2004 and began to implement it in 2005.

- The government identified as chief causes the limits in profit creation under the government agency's management system (lack of efforts in marketing, customer attraction, service differentiation, development of station buildings and appurtenant businesses, etc.) and the payment system not related to productivity.
- For the same reasons, there were a lot of overseas cases that the rail business ownership was transferred from a state-run agency to a profitable organization, which then succeeded in the management improvement.
- Therefore, Korea pursued a fundamental reformation by introducing an operating system based on a commercial profit-oriented agency.

Table 54 | Overseas Cases of Management Improvement through Restructuring

Country	Before	After
Japan	1,323.7 bill. Yen in the red (1986)	209.9 bill. Yen in the black (1995)
Germany	15.6 bill. Mark in the red (1993)	0.6 bill. Mark in the black (1997)
Sweden	525 mill. Krona in the red (1988)	129 mill. Krona in the black (2000)
France	15.2 bill. Franc in the red (1996)	0.1 bill. Franc in the black (2000)

Source: MoCT of Korea, 「Rail Industry Restructuring」, 2003

4) Korea's Rail Industry Restructuring Method

• Due to the problems associated with the state's direct control mentioned above, the government tried to restructure the rail industry, and its original policy was to found a corporation fully invested by the government and then privatize the industry step by step.

- But for the rail facilities such as tracks that were of public nature, the government decided to continue to own them and by expanding investments, only commercial activities such as customer attraction, ticket sales, train and station operation, and rolling stock maintenance were to be carried out by profitable organizations.

• Under the belief that the restructuring by way of an abrupt privatization of the rail organization would cause confusion in rail operation, the opinions were put forward that the rail operation should be undertaken by a corporation and the privatization be considered later. Thus, a corporation was established as the rail operator.

- In 2005, Korea Rail Corporation was founded and was entrusted with rail operation.
- Unlike the state-run agency, a corporation was capable of active sales activities outside

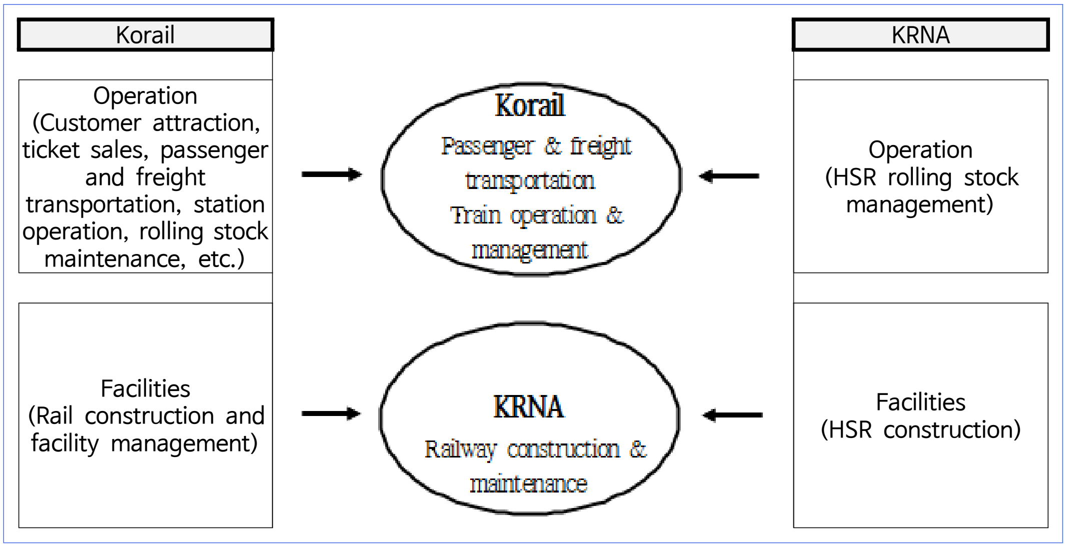
the restrictions of various laws and regulations such as Government Organization Law, Public Officials Law and Budget & Accounting Law, and furthermore, it was deemed possible to make the management more efficient.

Table 55 | Comparison of Laws Applicable to Government Agencies vs. Corporations

Category	Government Agency	Corporation
Asset Utilization	State-owned Property Law, Special Cast Law on State-owned Rails	Autonomously using the assets (As they are invested assets, they belong to the corporation.)
Organization & Staffing	Government Organization Law, Public Officials Law, Special Cast Law on State-owned Rails, Public Official Appointment Decree	Corporation Law, Fundamental Law on Management of Government-invested Organizations
Wages & Bonuses	Public Officials Law, Special Cast Law on State-owned Rails, Wage Regulation for Public Officials	Rules of the Corporation
Budget Planning & Operation	Budget & Accounting Law, Corporate Budget & Accounting Law (Accounting for Special Cases of Rails)	Budget Planning Standard of the Government to be applied; the Rules of the Corporation

Source: MoCT of Korea, 「Rail Industry Restructuring」, 2003

Figure 24 | Korea Rail Industry Restructuring



Note: Korea High-Speed Rail Construction Authority (KHRC) is a provisional organization built in 1992 for the construction of Gyeongbu (Seoul-Busan) HSR.

1.1.2. Rail-related Organizations of Korea

1) Ministry of Land, Infrastructure & Transport (MoLIT)

• MoLIT is responsible for national land, housing, construction, water resources and transportation.

• The Railway Bureau of MoLIT has nine departments including Rail Policy Dept., Rail Operation Dept., Rail Construction Dept., Metropolitan and City Rail Dept. and is responsible for establishing rail policies in Korea.
- In addition to these depts., the Railway Bureau also has Private Sector-invested Rail Team, Rail Safety Policy Dept., Rail Operation Safety Dept, and Rail Facility Safety Dept.

2) Korea Rail Network Authority (KRNA)

• KRNA, which was founded on 1 January 2004, is composed of 5 Divisions and 5 Regional Offices, and is responsible for:
- Constructing and managing rail facilities;
- Developing and operating commercial vicinity areas of stations and the wayside of rails after the construction of rail facilities;
- Rail crossings such as multi-level crossings; and
- Executing rail safety management and disaster prevention measures.

• As of the end of 2016, the number of the employees of KRNA is 1,428.

3) Korail

• Korail, which was founded on 1 January 2005, is composed of 7 Divisions and 12 Regional Offices, and is responsible for:
- Rail passenger and freight transportation and transportation business connected with rails;
- Rail equipment and rolling stock business; and
- Entrusted businesses such as rail facility maintenance and development of rail stations and their commercial vicinity areas.

• As of the end of 2016, the number of the employees of Korail is 27,127.

4) Research Institutes

- As national research & development institutes related to rails, there are Korea Transport Institute (KOTI) and Korea Railroad Research Institute (KRRI).
- KOTI is responsible for establishing rail policies and supports the government by performing policy researches such as the construction of high-speed rails of Korea.
- KRRI is responsible for developing rail technologies and performs researches on rail technologies such as the development of high-speed rolling stock.

5) Other

- Rolling stock manufacturers include Hyundai Rotem and Woojin Industrial Systems, and particularly, Hyundai Rotem has been developing high-speed rolling stock. The KTX Sancheon currently being operated is a Korean high-speed train produced by Rotem.

1.1.3. Construction Entities & Financing Methods by Rail Type

- In Korea, rails are divided into high-speed, conventional, metropolitan and urban rails, which are constructed by and funded by different entities.

- The construction of high-speed, conventional and metropolitan rails is managed by KRNA on behalf of the government, and the construction of urban rails is managed by local governments.

- The construction of private sector-invested rails is managed by private enterprises and is funded jointly by them and the government.

- The construction of conventional rails is funded entirely by the government; that of high-speed rails is funded jointly by the government and KRNA; and that of metropolitan and urban rails is funded jointly by the central and local governments.

- The construction entities and funding methods by rail type are as follows:

Table 56 | Construction Entities & Funding Methods by Rail Type

Rail Type	Construction Entity	Funding Method	Bases
High-speed rail	State (Agency: KRNA)	• Central Gov. 45% (Fund 35%, loan 10%) • KRNA 55%	Article 20 of Rail Construction Act; Gyeongbu HSR Constr. Plan (14 June 1993)
		• Central Gov. 50% • KRNA 50%	Article 20 of Rail Construction Act; The master plan for Gyeongbu HSR Phase 2 was amended on 23 Aug 2006.
		• Central Gov. 50% • KRNA 50%	Article 20 of Rail Construction Act; Honam HSR master plan (23 Aug 2006)
		• Central Gov. 40% • KRNA 60%	Article 20 of Rail Construction Act; Capital Region HSR master plan (31 Dec 2009)
Conventional rail	State (Agency: KRNA)	• Central Gov. 100%	Article 20 of Rail Construction Act; Funded by the project entity.
Metropolitan rail	State (Agency: KRNA)	• Central Gov. 70% • Local government 30% (In case of Seoul, central Gov. 50%, local government 50%)	Paragraph 2-1 of Article 10 of Special Act on Management of Metropolitan Transport and Article 13 of its Enforcement Decree
Conventional rail	State (Agency: KRNA)	• Central Gov. 100%	Article 20 of Rail Construction Act; Funded by the project entity.
Metropolitan rail	State (Agency: KRNA)	• Central Gov. 70% • Local government 30% (In case of Seoul, central Gov. 50%, local government 50%)	Paragraph 2-1 of Article 10 of Special Act on Management of Metropolitan Transport and Article 13 of its Enforcement Decree
Private sector-invested rail	Private enterprises	• The funding method to be determined by discussions between the government and the private sector. • The Incheon International Airport railway was funded by central Gov. 24.3% (land cost + construction subsidy) and private sector 75.7%.	Article 53 of Private Sector Investment Act on Social Infrastructure
Urban rail	Local governments	• Central Gov. 60% • Local government 40% (In case of seoul, state 40% and local government 60%)	Article 22-1 of Urban Railway Act; Standard on the Construction & Support of Urban Railways

Source: MoLIT, 「Rail Statistics」, 2016

1.2. Rail Operation Condition of Korea

1.2.1. Rail Length & Transportation Condition of Korea

1) Rail Lengths

- Total length of rails in Korea is 4,595.6 km as of 31 Dec. 2015, and the rate of double track is 65.3% and that of electrified rails is 75.1%.
- As for the rail lengths, conventional rails are the longest as 3,237.8 km and are followed by urban rails 642.6km, high-speed rails 596.3km, metropolitan rails 164.8km, and airport ails 61km.

Table 57 | Rail Lengths in Korea (as of 31 Dec. 2015)

Item	Total	Rails					Urban rails
		Sub-total	High-speed	Conventional	Airport	Metropolitan & other	
Total length (km)	4,595.6	3,953.0	596.3	3,237.8	61	164.8	642.6
Ratio of double track (%)	65.3	59.7	100	50.8	100	100	100
Ratio of electrified rails (%)	75.1	71.0	100	64.6	100	100	100

Source: MoLIT, 「Rail Statistics」, 2016

Figure 25 | Inter-regional Rail Networks in Korea

Source: Korea Railroad Corporation (Korail)

5) Rail Transportation Condition

• As of the end of 2015, the rail traffic volumes are 3,907,705,000 people/year for passengers and 37,904,000 tons/year for freight.

• As for passenger transportation, the traffic of urban rails, which operate within a region, is the highest as 2,522,901,000 people/year. It is followed by 74,959,000 people/year for conventional rails and then by 60,535,000 people/year for high-speed rails. Given their lengths, the utilization rate of high-speed rails is higher.

Table 58 | Rail Traffic Volumes of Korea (as of 31 Dec. 2015)

Category	Total	Rails				Urban rails
		Sub-total	High-speed	Conventional	Metro	
Passengers (1,000 persons)	3,907,705	1,384,804	60,535	74,959	1,249,310	2,522,901
Freight (1,000 tons)	37,094	37,094				-

Note: Rapid transit includes the metropolitan rails of Korail, ITX-Cheongchun, airport rails and Shin-Bundang Line.
Source: MoLIT, Rail Statistics, 2016

• The analysis of the yearly passenger transportation distances of rails indicates that currently, they are on the increase. Particularly, in the case of KTX, the transportation distance in 2015 was 151.5% of that in 2008. As such, it shows the highest growth trend.

• In the case of Saemaul Trains, their transportation distances tend to decrease due to the introduction of KTX.

• Among train classes, KTX represents the longest transportation distances, which in turn leads to the highest utilization rate.

• The passenger transportation share of rails was 12.4% in 2014 and was only 4.1% except for urban rails.

Table 59 | Railway Passenger Travel Distances

(10 Mill. person-km/year)

Category		2008	2009	2010	2011	2012	2013	2014	2015
Total	Person-km	1,845	1,769	1,898	2,158	2,209	2,260	2,284	2,322
	Index	100	95.9	102.9	117.0	119.7	122.5	123.8	125.9
KTX	Person-km	1,016	993	1,098	1,356	1,408	1,445	1,486	1,539
	Index	100	97.7	108.1	133.5	138.6	142.2	146.3	151.5
Saemaul	Person-km	180	169	167	147	124	118	129	135
	Index	100	93.9	92.8	81.7	68.9	65.6	71.7	75.0
Mugoonghwa	Person-km	649	606	634	655	677	697	669	648
	Index	100	93.4	97.7	100.9	104.3	107.4	103.1	100.2

Note: The indices mean the rates of passenger transportation distances in other years based on the passenger transportation distances in 2008.
Source: MoLIT, 「 Rail Statistics」, 2016

Table 60 | Passenger Transport Shares of Korea (as of 31 Dec. 2014)

Category	Total	Rail	Subway	Road	Marine Transport	Air
1,000 persons	30,507,071	1,263,472	2,526,167	26,678,513	14,271	24,648
Share (%)	100	4.1	8.3	87.4	0.1	0.1

Source: MoLIT, 「National Transport Statistics Year Book」, 2015

1.2.2. Rail Management Condition

1) Korea Rail Network Authority (KRNA)

- In 2015, the budget of KNRA rose to 11,057.3 billion KRW or 1,812.3 billion KRW up from the previous year. 57% of its total budget was from the state coffers and the remaining 43 was funded on its own.

- The total budget of projects is 8,455.7 billion KRW. Of it, the project budget for conventional rails is the highest and is followed by high-speed rails, maintenance, entrusted works, metropolitan rails, facility upgrade and other projects in order.

Table 61 | Breakdown of KRNA's Budget

Unit : 100 mill. KRW

Item	Budget 2014	Budget 2015	Compared with the previous year
Total	92,450	110,573	18,123
- State subsidy	50,687	63,842	13,155
- Self-funded	41,763	46,731	4,968
Project costs	67,148	84,557	17,409
- High-speed rails	21,217	12,819	-8,398
- Conventional rails	24,580	46,593	22,013
- Metropolitan rails	4,013	5,506	1,493
- Other projects	2,625	838	-1,787
- Entrusted works	4,296	6,185	1,889
- Facility upgrade	3,173	4,876	1,703
- Maintenance cost	7,244	7,740	496
Management cost	1,292	1,633	341
- Labor cost	1,197	1,242	45
- Operating cost, etc.	321	391	70
Principal and interest of loans	23,748	24,346	598
Contingency	37	37	0

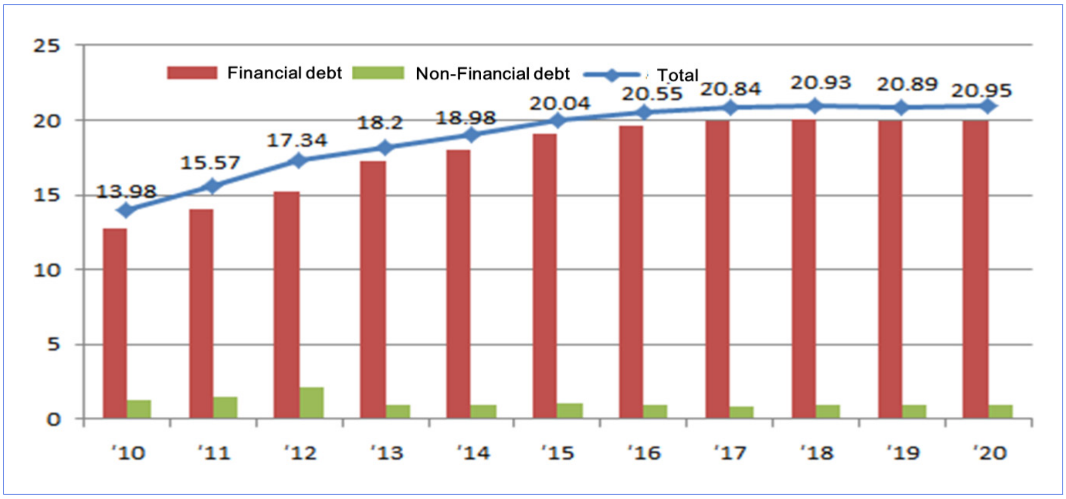
Source: MoLIT, 「Rail Statistics」, 2016

- KRNA's financial debt caused by the construction of high-speed rails is 19.0 trillion KRW (as of the end of 2015) and is anticipated to reach 20.9 trillion KRW in 2020.

Table 62 | KRNA's Financial Condition

Item	2013	2014	2015	Change
Asset (A)	16.353 trillion KRW	17.814 trillion KRW	18.730 trillion KRW	5.8%
Debt (D)	18.198 trillion KRW	18.979 trillion KRW	20.381 trillion KRW	5.6%
Equity (E)	△1.845 trillion KRW	△1.898 trillion KRW	△1.965 trillion KRW	3.5%
Debt ratio (D/A)	111.3%	111.1%	110.9%	△0.2%
Current net income	△95.8 bill. KRW	△29.0 bill. KRW	△73.0 bill. KRW	151.7%

Figure 26 | KRNA's Present & Prospective Debts



- The revenue of KRNA comes from the track access charges collected from Korail and SRT, which are rail operators, but in the case of high-speed rails, the amount collected as track fees falls short even of the interest, resulting in accumulated deficits.
  - According to the Mid- and Long-term Financial Management Plan for Years 2015 to 2019 (Sep. 2015), the track access charges for high-speed rails are 34% of Korail's operating income and 50% of the new operator SRT's operating income. In the future, unit track fees are planned to be applied..

Table 63 | Track Access Charges Collected from High-speed Rails

Unit : 100 Mill. KRW

Category	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Track access charge (A)	960	1,453	1,655	1,824	1,822	1,644	1,915	2,729	3,156	3,409	3,525	4,911
Maintenance cost (B)	1,071	1,557	1,482	729	808	717	878	990	891	911	931	1,254
Debt repayment fund (C=A-B)	△111	△104	173	1,095	1,014	927	1,037	1,739	2,265	2,498	2,594	3,657
Interest cost (D)	2,003	2,764	3,084	3,555	3,305	4,111	4,627	4,415	4,416	4,615	4,400	5,744
Interest repayment rate (C/D)	-	-	5.6%	30.8%	30.7%	22.5%	22.4%	39.4%	51.3%	54.1%	59.0%	63.7%
Shortfall of interest cost (E=D-C)	2,115	2,867	2,911	2,460	2,291	3,184	3,590	2,676	2,151	2,117	1,806	2,087

Note: The track access charge and maintenance cost are exclusive of VAT.
Source: MoLIT, 「Rail Statistics」, 2016

6) Management Condition of Korail

- The budget for 2016 is 6.3518 trillion KRW; the expense budget is 5.6115 trillion KRW; and the capital budget is 740.3 billion KRW.

Table 64 | Korail's 2016 Budget Breakdown

Unit : 100 Mill. KRW

Category	Profit Budget	Category	Expense Budget
Total	59,070	Total	56,115
• Turnover	57,788	Cost of sales	54,703
- Transport profit	41,722	Selling & admin expenses	2,253
- Profit from multiple	3,124	Other costs	2,045
- Consignment business profit	12,942	Financial cost	4,292
• Other profits	1,050	Corporate tax	△9,151
• Financial profit	232	Contingency	1,973

Source: MoLIT, 「 Rail Statistics」, 2016

- The debt of Korail is 13 trillion KRW as of the end of 2015 or about 2.2 times up from 5 trillion KRW of 2007.

Table 65 | Korail's Financial Condition

Unit : 100 Mill. KRW

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total assets	142,137	160,075	186,110	198,123	191,183	170,182	187,190	186,518	178,690
Equity	82,652	92,112	98,563	101,543	83,115	54,070	41,307	36,183	46,612
Debt	59,485	67,963	87,547	96,580	108,068	116,112	145,883	150,335	132,078
Debt ratio	72.0%	73.8%	88.8%	95.1%	130.0%	214.7%	353.2%	415.5%	283.4%

Source: MoLIT, 「Rail Statistics」, 2016

Table 66 | Korail's Yearly Business Accounts

Unit : 100 Mill. KRW

Category	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Oper. revenue	18,643	34,029	35,302	35,703	36,314	35,288	36,825	39,745	43,049	45,528	48,076	52,207
Oper. expense	21,053	39,402	40,639	42,117	43,688	42,149	42,112	44,968	46,640	47,460	47,042	51,063
Oper. profit & loss	△2,410	△5,373	△5,337	△6,414	△7,374	△6,861	△5,287	△5,223	△3,591	△1,932	1,034	1,144
Non-oper. revenue	862	2,499	4,087	9,474	25,937	24,791	18,089	20,243	8,457	1,978	3,120	9,263
Non-oper. expense	33	3,188	4,010	3,182	10,893	7,534	6,955	8,675	33,396	53,702	8,969	6,778
Non-oper. profit & loss	829	△689	77	6,292	15,044	17,257	11,134	11,568	△24,939	△51,724	△5,849	2,485
Current net income	△1,439	△6,062	△5,260	1,333	5,140	6,486	3,808	3,123	△28,737	△44,672	△4,754	5,776

Source: MoLIT, 「Rail Statistics」, 2016

- Korail's revenue source is the transportation by rail, which has grown continuously over the recent decade.

- As for the passenger transportation revenue, KTX takes up the largest percentage, and the revenue is on the increase, but the revenue from Saemaul Trains is on the decrease.

- Major cargoes include cement, containers and coal.

Table 67 | Korail's Revenue from Rail Transportation

Unit: 100 Mill. KRW

Item	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Grand total	22,938	23,863	25,241	23,574	25,104	28,098	30,360	31,888	33,356	36,352
• Passenger	19,743	20,340	21,396	20,333	21,810	24,627	26,823	28,324	29,662	32,702
- KTX	9,862	10,150	10,412	10,183	11,387	13,853	15,056	16,054	16,723	19,267
- Conventional Train	5,217	5,013	5,033	4,668	4,773	4,797	5,005	5,052	5,172	5,151
• Saemaul	1,576	1,470	1,488	1,421	1,401	1,335	1,199	1,151	1,275	1,348
• Mugunghwa	3,456	3,387	3,472	3,159	3,363	3,397	3,733	3,850	3,850	3,759
• Commuter train	125	91	73	36	10	5	5	7	5	3
• Miscellaneous	60	65		52		60	68	44	42	41
- Urban Metro	4,664	5,177	5,951	5,482	5,650	5,977	6,762	7,218	7,767	8,284
• Freight	3,170	3,524	3,845	3,241	3,294	3,471	3,537	3,564	3,694	3,650
- Subtotal	3,108	3,393	3,714	3,096	3,123	3,230	3,324	3,308	3,429	3,392
• Cement	919	1,012	1,194	1,073	996	1,000	986	1,020	1,039	1,140
• Container	905	982	1,073	701	807	993	1,080	1,082	1,055	948
• Coal	525	515	535	529	519	463	439	403	409	357
• Ores	159	166	179	176	162	165	173	160	201	192
• Oils	166	184	164	166	150	131	122	110	130	181
• Fertilizers	21	25	30	17	17	14	11	10	3	5
• Constr.	60	63	41	51	52	56	52	31	36	34
• Cheongyong	-	-	-	-		-	-	-	-	-
• Other	353	446	498	383	420	408	461	492	556	535
- Miscellaneous	62	131	131	145	171	241	213	256	265	258
• Parcels	25	-	-	-	-	-	-	-	-	-

Source: MoLIT, 「Rail Statistics」, 2016

1.2.3. Rail Investment Condition

• The amount invested on the SOC for land transportation in 2016 was about 20 trillion KRW, of which about 7 trillion KRW or about 33% was invested on rails (about 36%, if urban rails are included).

• The amount invested on rails in 2011 was about 4 trillion KRW, which amounted to only about 20% of total investment. According to the government's policy to expand the investment on rails in the early 2010s, the investment rates have grown continuously.

Table 68 | Present Condition of the Investment on Land Transportation

Unit: 100 Mill. KRW

Category	2011		2012		2013		2014		2015		2016	
	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
SOC total	215,153	100	197,600	100	216,944	100	206,433	100	217,549	100	207,632	100
(Growth rate)	-1.8		-8.2		-9.8		-4.8		-5.4		-4.6	
Roads	72,032	33.5	75675	38.3	89,344	41.2	83,912	40.6	90,168	41.4	82,803	39.9
Rails	44,338	20.6	50876	25.7	61,380	28.3	61,800	29.9	67,463	31.0	70,032	33.7
Urban rails	9,717	4.5	10265	5.2	7,761	3.6	6,232	3.0	6,588	3.0	4,614	2.2
Aviation & airports	679	0.3	698	0.4	830	0.4	1,008	0.5	1,360	0.6	1,642	0.8
Logistics & other	19,820	9.2	11935	6.0	12,159	5.6	12,683	6.1	12,436	5.7	13,259	6.4
Water resources	50,182	23.3	29020	14.7	27,694	12.8	23,830	11.5	22,731	10.4	21,496	10.4
Regions & cities	8,574	4.0	8827	4.5	8,034	3.7	7,978	3.9	7,899	3.6	7,506	3.6
Industrial complexes	9,811	4.6	10304	5.2	9,742	4.5	8,990	4.4	8,904	4.1	6,280	3

Source: Budget for MoLIT of the fiscal year 2016 and fund operation plan (draft), 2016

• Korea's total investment on rails in 2016 was about 5.6 trillion KRW or about 1.6 times up from a decade ago (2007).

- The investment amounts on urban rails and high-speed rails decreased while those on conventional rails and metropolitan rails, which are implemented by the speed-up of existing lines and the construction of (semi) high-speed rails, are on the increase.

Table 69 | Investment Condition by Rail Type

Unit: 100 Mill. KRW

Year	Total	Conventional rails	High-speed rails	Urban rails	Metropolitan rails
2016	56,573	45,286	800	4,614	5,873
2015	57,357	40,098	5,312	6,588	5,359
2014	53,650	26,354	17,928	6,233	3,135
2013	54,038	26,350	16,600	7,750	3,338
2012	48,639	18,348	13,850	10,241	6,200
2011	42,937	15,845	9,000	9,670	8,422
2010	42,975	16,886	5,700	11,488	8,901
2009	52,992	22,772	6,085	15,873	8,262
2008	39,983	15,587	4,209	13,853	6,334
2007	35,365	14,006	3,211	12,845	5,303
2006	35,076	14,056	3,700	12,960	4,360
2005	34,752	16,398	2,850	11,642	3,862
2004	31,174	15,073	4,833	8,185	3,083
2003	34,421	18,216	6,543	7,718	1,944
2002	30,450	13,095	7,810	8,029	1,516

Note: The amounts for rail safety, operation and R&D are excluded.
Source: MoLIT, 「Rail Business Handbook」, 2016

- The finances for the investment on rails are shared by the central and local governments and the private sector in accordance with project cost shares of different rail types.

- Even the investment on rail projects by private investors is being made in various forms such as BTO and BTL, and the government is recently pursuing to vitalize the rail business invested by the private sector.

Table 70 | Investment on Rail Projects by Financial Source

Unit: 100 Mill. KRW

Financial source		1980	1990	2000	2007	2008	2009	2010	2011	2012	2013	2014	2015
High-speed rail	Central Gov.				3,211	4,209	6,085	5,700	9,000	13,850	16,600	17,928	5,312
	Local Gov.				-	-	-	-	-	-	-	-	-
	Private sector				-	-	-	-	-	-	-	-	-
	Other				5,286	8,018	11,693	12,788	11,590	10,926	15,800	3,489	7,507
	Sub total				8,497	12,227	17,778	18,488	20,590	24,776	32,400	21,417	12,819
Conventional rail	Central Gov.	334	2,078	7,287	14,006	15,587	22,772	16,886	15,845	18,348	26,350	26,354	40,098
	Local Gov.				-	-	-	-	-	-	-	-	-
	Private sector				5,008	3,160	5,642	7,367	3,694	-	1,918	-	-
	Other				396	1	1	864	183	181	-	86	-
	Sub total	334	2,078	7,287	19,410	18,748	28,415	25,117	19,722	18,529	28,268	26,440	40,098
Metropolitan rail	Central Gov.			942	5,303	6,334	8,262	8,901	8,422	6,200	3,338	3,135	5,359
	Local Gov.			329	2,927	2,412	3,369	2,815	2,819	3,531	1,106	871	967
	Private sector				930	1,316	1,850	1,337	2,043	-	-	-	-
	Other				682	1,903	1,503	582	488	-	1,638	1,269	890
	Sub total			1,271	9,842	11,965	14,984	13,635	13,772	9,731	6,082	5275	7,366

Source: MoLIT, 「Rail Business Handbook」, 2016

1.3. Rail Development History of Korea

1.3.1. Industrialization Era

- As the country was industrialized rapidly owing to the 5-year economic development plans, Seoul grew to a super city with a population over 3 million in 1970, and the cities around Seoul also sprawled with traffic jams worsening during rush hours.

- Also, industrial lines such as Yeongdong, Taebaek and Central Lines for the transportation of industrial resources and energy such as cement and coals, which served as driving forces for the economic development, reached their limits, not meeting the freight demand that had soared.

- Even in the passenger transportation, with the successive openings of highways such as Gyeongin, Gyeongsu and Gyeongbu in late 1960s and early 1970s and the supply of vehicles, the country sought after a development in the quality of services and speeds in order to make rails more competitive.

- Thus, according to the then President's instructions, railway electrification projects were implemented with government subsidies. Between 1967 and 1970, technical studies were completed for the electrification of industrial lines, and in 1975, all the sections of industrial lines were completely electrified.

- Beginning from 1972, electric locomotive began to be introduced, and as the Seoul metro system was opened for the capital region, a new era of electric railways was hailed.

1.3.2. Introduction of a High-speed Rail

- Beginning from early 1970s, the need of a high-speed rail project was raised as a way of making up for the short capacities of Gyeongbu Expressway, which was the basic axis for the national logistical network.

- Along the Seoul-Busan corridor, about 70% of the total population and regional production of the country were concentrated. The corridor also handled 60% of total passenger traffic and 70% of freight nationwide. In those days, the traffic volumes of passengers and freight tended to grow 3.6% and 4.3% a year, respectively.

- Along the Gyeongbu Expressway, however, shipping difficulties were occurring in 38% of the entire corridor. After 1970s, the rail services was improved in quality due to the railway electrification, but as road-centered transport policies were being implemented together with the establishment of the expressway network, the railways became less and less competitive.

- Particularly as the Suwon~Daejeon Highway (125.3 km) reached its capacity limit, it was impossible to add any more road traffic.

Table 71 | Investment Amounts on Transport Facilities

Economic Development Plans	Roads	Rails	Metro	Airports	Ports	Total
1st (1962~1966)	61(17.2)	215(60.6)	-	26(7.3)	53(14.9)	355
2nd (1967~1971)	1,147(52.0)	634(28.7)	83(3.8)	76(3.4)	267(12.1)	2,207
3rd (1972~1976)	4,674(51.6)	2,669(29.4)	248(2.7)	189(2.1)	1,284(14.2)	9,064
4th (1977~1981)	16,302(47.7)	7,434(21.7)	5,532(16.2)	1,469(4.3)	3,451(10.1)	34,188
5th (1982~1986)	37,191(46.7)	9,647(12.1)	24,379(30.6)	2,223(2.8)	6,186(7.8)	79,626
6th (1987~1991)	115,225(79.6)	14,620(10.1)	789(0.5)	2,538(1.8)	11,538(8.0)	144,710

Note: The rates in ( ) are the percentages of total amounts in %.
Source: Ministry of Strategy & Finance

- At that time, the industrial lines and the electrification project for the capital region in Korea were coming to the finish, and France and Japan, which had been participating in the project, proposed the construction of a new high-speed rail along the Seoul-Busan corridor.

- An advisory group for the assessment of Korean government policies, too, suggested the construction of a new railway as a way to enhance the transporting capacities of the Gyeongbu Line, and Korea Institute of Science & Technology made an independent recommendation that a railway be built along the Seoul-Busan corridor.

- Based on this recommendation, the government incorporated the construction of a high-speed rail between Seoul and Daejeon into the 5th 5-year socio-economic development plan in 1981.

- In 1989, the government established the Regulation on High-speed Rail & New International Airport Construction Promotion Committee, organizing a committee with the Vice Prime Minister as the chief and relevant Ministers and professional experts as its members.

- On top of that, a working-level committee was made up of the Vice Minister of Transportation as the chief and the Directors of relevant Ministries as its members, and then the project was commenced in full force.

- In October of the same year, about 100 experts were invited from 11 countries around the world including advanced countries such as France, Germany and Japan, and a symposium on high-speed rails was held in Seoul.

- In 1989, a policy to proceed with the construction of Gyeongbu (Seoul-Busan) high-speed rail with an average speed of 200 km/h or above was determined, and technical investigations were conducted with regard to train operation, rolling stock structure, and civil works together with an analysis of systems.

- In 1991, the RFP for the selection of high-speed rail rolling stock was issued; in 1993, negotiations were started with France; and in 1994, an agreement was signed for the introduction of rolling stock in 1994.

- In 2004, beginning with the opening of the Gyeongbu HSR Phase 1, the era of high-speed rails was opened in Korea.

- The construction cost, which had originally been earmarked as 5.8 trillion KRW, rose to 10 trillion KRW in 1993 with the first amendment of the plan, to 17.5 trillion KRW in 1994 with its second amendment, and then to 19.2 trillion KRW in 1998 with its third amendment.

- Accordingly, Daejeon and Daegu stations, which had been planned to be mined for the sake of construction cost savings considering the national financial condition, were designed to be built on the ground, and it was decided to utilize the existing Seoul~Anyang line for the underground sections of NamSeoul~Seoul~Susaek.

- As the construction of the high-speed line in the Gyeongbu HSR Phase 2 was finished up on 1 Nov. 2010, it became possible to reduce the travel time further.

- After the opening of Phase 1, the Seoul-Busan travel time of 4 hours 10 minutes was reduced to 2 hours 40 minutes due to its opening. After the opening of Phase 2, the travel time was reduced to 2 hours 18 minutes.

- As Osong, Kimcheon, ShinGyeongju and Woolsan Stations were newly built thereafter, KTX began to stop at more stations with wider areas benefiting from the services.

- When the Gyeongbu HSR Phase 1 was opened in 2004, high-speed trains were mobilized for the existing Honam Line, too, but the Seoul-Daejeon section was shared between the new high-speed trains and some speedy trains for the conventional Gyeongbu Line while the Daejeon~Gwangju~ Mokpo section was utilized by electrifying the existing Honam Line.

- As high-speed trains were operated in the Daejeon~Mokpo section by utilizing the existing line, the high-speed trains were operated at a lower speed than in the new high-speed rail sections.

• In 2009, the Honam HSR Phase 1 Project (Osong~Gwangju) was launched to build a new high-speed rail along the Honam corridor and was opened in 2015.

• The Honam HSR Project Phase 2 (Gwangju~Mokpo) was commenced in January 2017 and is scheduled to be opened in 2018. The overview of the Honam HSR Project is as follows:

Table 72 | Overview of the Honam HSR Construction Project

Category	Description	
Project Route	Osong~Songjeong of Gwangju~Mokpo 243.4㎞ (Osong~Songjeong of Gwangju 182.3 km; Songjeon of Gwangju~Mokpo 61.1 km) ※ The Seoul~Osong section is shared by the existing Gyeongbu HSR (121.3 km).	
Stations	Osong, Gongju, Iksan, Jeongup, Songjeong of Gwangju, Mokpo (Imseongni) stations	
Project Period	2006 to 2018 (Osong~Songjeong of Gwangju opened in 2015; Songjeong of Gwangju~Mokpo scheduled to be opened in 2018.)	
Project Cost	10.1345 trillion KRW	
Operating Speed	300km/h (Design speed 350km/h)	
Travel Time	Seoul~Songjeong of Gwangju (opened in 2015)	Seoul ~Mokpo (scheduled to be opened in 2018)
	93 min. by KTX; 66 min. shorter than by Saemaul Trains (159 min.)	122 min. by KTX; 63 min. shorter than by Saemaul Trains (185 min.)
Funding	National treasury 50%; Funded by KRNA 50%	
Train Consist	A total of 220 cars (10-car train consist)	
R/S Depot	1 no. (in Gwangju)	

Source: MoLIT, 「Rail Statistics」, 2016

• As the demand for high-speed rails increased, high-speed rails were built between Suseo and Pyeongtaek in 2009 due to the limits in track capacities between Seoul Station and Geumcheon-gu Office, where high-speed trains were being operated along the Gyeongbu and Honam corridors, and in order to expand the benefits of high-speed rail services in southern Gyeonggi Province and southeastern Seoul.

• Originally, it was going to select a private business partner and operate the system, but because of both Korail's objection and the public's opposing opinions, SR Company was founded as a subsidiary company of Korail to operate high-speed trains.

• The Suseo~Pyeongtaek HSR was launched in its construction in 2011 and was opened in 2016, and the project overview is as follows:

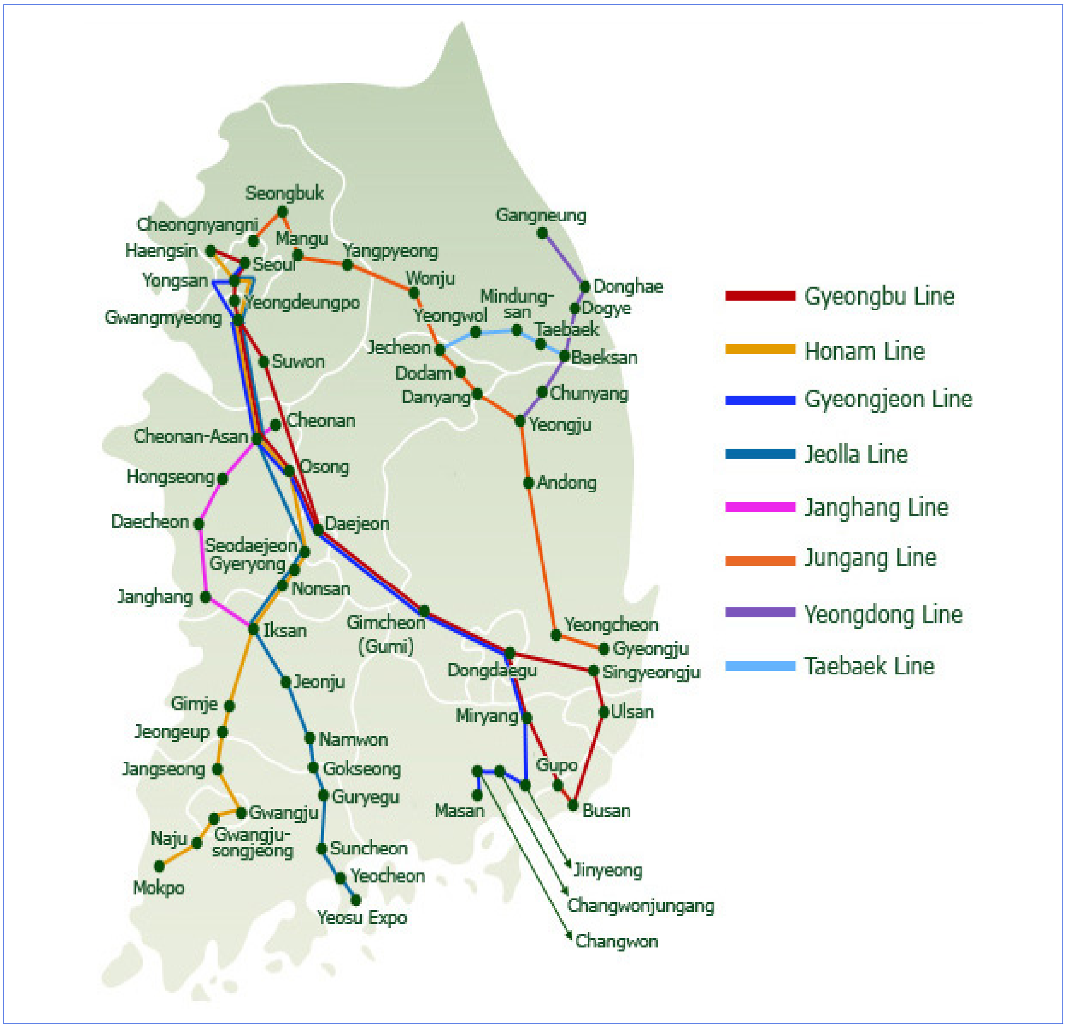
Table 73 | Overview of the Suseo HSR Construction Project

Category	Description
Project Route	Suseo~Dongtan~ Pyeongtaek (61.08 km)
Major Facilities	Suseo Station, Dongtan Station, Jijae Station, Suseo Depot
Project Period	2008~2016
Project Cost	3.1272 trillion KRW
Operating Speed	300km/h (Design speed 350km/h)
Travel Time	Suseo~Pyeongtaek 21 min.; Suseo~Busan 129 min.; Suseo~Mokpo 112 min. (if the Songjeong of Gwangju~Mokpo section is completed in the Honam Line)
Funding	National treasury 40%; KRNA 60%

Source: MoLIT, 「Rail Statistics」, 2016

• In addition, high-speed trains are being operated along the existing rail lines interfaced to the high-speed rail lines in order to expand the beneficiary and influential areas of the high-speed rails.
  - In connection with the Gyeongbu HSR, KTX trains are being operated in Pohang, Changwon, Jinju and other areas; and in connection with the Honam HSR, they are being operated in Jeonju, Suncheon and Yeosu.

Figure 27 | KTX Rail Network



1.3.3. Private Sector-invested Rail Projects

1) Introduction of a Private Sector Investment System

• From 1960s to 1994, the private sector investment projects of Korea were executed sporadically under individual laws (Road Law, Port Law, etc.) by different disciplines and their scales were very small.

• In 1994, the government enacted the Act on Private Capital Attraction for Social Infrastructure and implemented private investment projects chiefly with a BTO (Build-Transfer-Operate) scheme, but at the initial stage, the private sector's participation was low due to the lack of project experience and the immaturity of the financial market.

• To induce the private sector's participation, the government fully amended the relevant law into the Act on Private Sector Investment on the Social Infrastructure in 1998, preparing a system for minimum revenue guarantee (MRG).

Table 74 | Transition History of the Private Investment Project Promotion System of Korea

Period	Description
1968-1993	• Implementing private investment projects under individual laws (Road Law, Port Law, etc.)
1994-1997	• Enacting the Act on Private Capital Attraction for Social Infrastructure • Inducing people's participation in private investment projects through a well-organized process • Lack of project experience, the government's failure to play a proper role and poor business activation due to excessive restrictions
1998-2004	• Providing the government's support by amending relevant laws (introduction of MRG) • Adverse effects of the MRG system
2005-Present	• Introducing new private investment business schemes such as BTL and a investment risk sharing system • Abolishing a system of minimum revenue guarantee and vitalizing infrastructure funds through public subscription • Performing an eligibility survey for private sector-proposed projects

Sources: 1) Korea Transport Institute, 「Methods of Introducing a Post Eligibility Assessment System for Private Sector-invested Rail Projects」, 2016
2) Ministry of Strategy & Finance, 「Economic Development Experience Modularization Project: Private Investment Projects of Korea」, 2013

• The MRG system, however, caused an enormous financial burden, encountering with a serious social criticism, which posed a bigger obstacle to the activation of private investment projects.

• To help solve these problems, the relevant law was amended in 2005 and a new BTL (Build-Transfer-Lease) scheme was introduced.

• Afterwards, the government abolished the MRG system completely in 2009, introduced new schemes for private investment projects such as BTO-rs through the revision of the Master Plan for Private Investment Projects in 2015, and has made efforts to improve the systems for a better attraction of private capitals until today.

2) Current Situation of Private Sector Rail Projects

• The first of the private sector-invested rail projects of Korea ("PSI rail projects") was the Incheon International Airport rail, which was commenced in construction in 2001 and opened in 2007.

• After that, the PSI rail projects under the supervision of the Ministries of the central government and local governments were expanded, and at present, the PSI rail projects are being pursued in BTO and BTL schemes.

• Of the PSI rail projects of Korea, nine rails are currently being operated, two under construction and another two being arranged for construction. The overview of each project is as shown below.

Table 75 | List of the Private Sector-invested Rail Projects of Korea

Project Title	Present Condition	Business Scheme	Total Project Cost (100 Mill. KRW)	Opening Year	Operating Period
Incheon International Airport Rail	Under operation	BTO	32,957	Phase 1: 2007.3 Phase 2: 2010.12	30 years
ShinBundang Line (Gangnam-Jeongja) Double-track	Under operation	BTO	11,690	2011.12	30 years
ShinBundang Line (Jeongja-Gwanggyo) Double-track	Under operation	BTO	10,257	2016.1.30	30 years
Line 9 Phase 1	Under operation	BTO	9,145	2009.7.24	30 years
Busan-Gimhae LRT	Under operation	BTO	7,742	2011.9.17	30 years
Yongin LRT	Under operation	BTO	7,278	2013.4.16	30 years
Uijeongbu LRT	Under operation	BTO	5,477	2012.7.1	30 years
Jeolla Line (Iksan-Shilli) Double-track	Under operation	BTL	6,172	2011.1	20 years
Gyeongjeon Line (Haman-Jinju) Double-track	Under operation	BTL	3,383	2012.12	20 years
Ui-Shinseol LRT	Under construction	BTO	6,465	Scheduled to be 2017.7	30 years
Sosa-Wonsi Double-track Metro	Under construction	BTL	15,495	Scheduled to be 2018.2	20 years
Bujeon-Masan Double-track Metro	Under construction	BTL	14,303	Scheduled to be 2020	20 years
ShinBundang Line (Yongsan-Gangnam) Double-track Metro	Construction being arranged	BTO	8,721	Scheduled to be 2022	30 years
Daegok-Sosa Double-track Metro	Construction being arranged	BTL	11,628	Scheduled to be 2020	30 years

Source: Korea Transport Institute, 「Methods of Introducing a Post Eligibility Assessment System for Private Sector-invested Rail Projects」, 2016

1.3.4. Construction of Urban Rails

• Due to the rapid increase in the population after 1960s, the transport demand soared in metropolitan cities, and the car-oriented transportation system revealed its limits in easing the transport demand.

• To solve these problems, a plan to construct urban rails was pushed forward.

• As for the urban rails in Korea, Seoul Metro Line 1 (between Seoul Station and Cheongnyangni) began to be constructed in 1971 and was opened for the first time in 1974.

• After that, a rail network was developed by connecting Seoul Metro Line 1 with the Gyeonggin Line, Gyeonggbu Line, Gyeongwon Line and others that had already been operated, and in order to solve the traffic problems associated with the growth of new cities around Seoul, the urban rail network was continuously expanded in the capital region.

• In 1985, an urban rail system was opened in Busan, and urban rails were opened in Daegu in 1997, in Daejeon in 2006 and in Gwangju in 2008. Like this, the construction of urban rails proceeded continuously in an effort to solve the challenges of urban transportation.

• The present operating condition of the urban rails is as follows:

Table 76 | Present Operating Condition of the Urban Rails in Korea

Category	Line	Operating Length (㎞)	No. of Stations	Section	Capacity (onboard)	Opening Date (Initial)
Total	22 lines	642.6	626	-	2,523	-
Seoul (9)	Line 1	7.8	10	Seoul Sta.~Cheongnyangni	107	’74.08.15
	Line 2	60.2	50	Seongsu~Seongsu	567	’80.10.31
	Line 3	38.2	34	Juchuk~Ogeum	203	’85.07.12
	Line 4	31.7	26	Danggogae~ Namtaeryeong	225	’85.04.20
	Line 5	52.3	51	Banghwa~Sangil, Macheon	219	’95.11.15
	Line 6	35.1	38	Ungam~Bonghwasan	133	’00.08.07
	Line 7	57.1	51	Jangam~Bupyeonggu Office	267	’96.10.11
	Line 8	17.7	17	Amsa~Moran	61	’96.11.23
	Line 9	31.5	30	Gaehwa~Sports Complex	102	’09.07.24.
	Sub total	331.6	307		1,884	

Table 77 | Present Operating Condition of the Urban Rails in Korea (Continued)

Busan (4)	Line 1	32.5	34	Nopo~Shinpyeong	162	’85.07.19
	Line 2	45.2	43	Jangsan~Yangsan	118	’99.06.30
	Line 3	18.1	17	Daejeo~Suyeong	33	’05.11.28
	Line 4	12.0	14	Anpyeong~Minam	11	’11.03.30
	Sub total	107.8	108		324	
Daegu (3)	Line 1	25.9	30	Daegok~Ansim	69	’97.11.26
	Line 2	31.4	29	Moonyang~Yeongnam Univ.	65	’05.10.18
	Line 3	23.1	30	Chilgok-gyeongdae Hospital~Yongji	17	‘15.04.23
	Sub total	80.4	89		151	
Incheon	Line 1	29.4	29	Gyeyang~International Business District	72	’99.10.06
Gwangju	Line 1	20.5	20	Nokdong~Pyeongdong	18	’04.04.28
Daejeon	Line 1	20.5	22	Panam~Banseok	41	’06.03.16
Busan -Gimhae	Busan-Gimhae	23.2	21	Sasang~Gayadae	17	’11.09.17
Uijeongbu	Uijeongbu	11.1	15	Balgok~Tapseok	10	’12.07.01
Yongin	Yongin	18.1	15	Giheung~Jeondae	6	`13.04.26

Note: The capacities are based on the year 2015 and in units of million people/year.
Source: MoLIT, 「Rail Statistics」, 2016

- On the other hand, there are a total of seven metropolitan rails with a total length of 164.8 km.
  - In a broad sense, metropolitan rails can be considered as urban rails, but the reason why they are classified as metropolitan rails is that their funding shares between the central government and local governments are different from those of urban rails.

Table 78 | Present Operating Condition of Metropolitan Rails

Category	Type	Line	Section	Rail Length (km)	Opening Date (Initial)
Korail (146.3km)	Conventional and Metropolitan (106.9km)	Central Line	Cheongnyangni~Deokso	18.0	'05.12.16
		Gyeongeui Line	Yongsan~Gongdeok	1.9	'14.12.27
			Gongdeok~DMC	6.1	'12.12.15
			DMC~Munsan	40.6	'09. 7. 1
		Gyeongchun Line	Mangwoo~Geumgok	18.0	'10.12.21
		Gyeongwon Line	Eujeongbu~Dongducheon	22.3	'06.12.15
	Metropolitan (39.4km)	Bundang Line	Wangsimni~Seolleung	6.7	'12.10. 6
			Ori~Jukcheon	1.8	'07.12.24
			Jukjeon~Giheung	5.1	'11.12.28
			Giheung~Mangpo	7.4	'12.12. 1
			Mangpo~Suwon	5.2	'13.11.30
		Su-In Line	Oido~Songdo	13.1	'12. 6.30
	Sub-total			133.1	
Neo Trans Co. Ltd.	Metropolitan (18.5km)	ShinBundang Line	Gangnam~Jeongja	18.5	'11.10.28
	Grand Total			156.8	

Source: MoLIT, 「Rail Statistics」, 2016

1.4. Rail Investment Plan

- In the third master plan for the establishment of national rail networks, which is Korea's rail investment plan, six concepts of developing rail projects were suggested in order to embody safe and convenient railways, bring about regional development and ensure project competitiveness and efficiency.
  - The six concepts include enhanced rail efficiency, high-speed mobility between major areas, eased traffic jams in metropolitan cities, safe and convenient installations, higher competitiveness of rail logistics and the establishment of an integrated rail network in the Korean Peninsula in preparation for the reunified Korea.

- In the third master plan for the establishment of a national rail network, thirty new projects were programmed in order to achieve the six concepts.

- To this aim, a total of 70.4 trillion KRW has been planned to be spent between 2016 and 2025.
  - For the planned period, 7.8 trillion KRW, 38.4 trillion KRW and 24.2 trillion KRW are prospected to be spent for high-speed, conventional, and metropolitan rails, respectively.
  - Based on the national treasury, 3.1 trillion KRW, 29.6 trillion KRW and 10.4 trillion KRW are going to be input for high-speed, conventional, and metropolitan rails, respectively.

- The funds for the investment are planned to be supplied in the following way: 43.1 trillion KRW from the national treasury, 3.0 trillion KRW from local governments, 19.8 trillion KRW from private capital attraction and 4.5 trillion KRW from others including KRNA's stocks.

Table 79 | Investment Plan by Rail Sector of Korea

Unit: 100 Mill. KRW

Category		Total Project Cost	2011~2015	2016~2020	2021~2025	Planned Period (2016~2025)	Planned Period (After 2025)
High-speed Rails	Sub total	259,763	181,232	38,491	40,040	78,531	-
	National Treasury	119,230	87,787	15,425	16,018	31,443	-
	Private Capital	29,155	-	7,021	22,134	29,155	-
	Sub total	111,378	93,445	16,045	1,888	17,933	-
Conventional Rails	Sub total	645,731	146,821	199,198	184,989	384,187	114,723
	National Treasury	528,571	131,778	156,053	139,846	295,899	100,894
	Local government	2,298	1,998	300	-	300	-
	Private capital	114,862	13,045	42,845	45,143	87,988	13,829
Metropolitan Rails	Sub total	366,213	36,393	109,449	132,273	241,722	88,098
	National Treasury	163,664	16,894	48,668	54,989	103,657	43,113
	Local government	46,083	6,071	18,724	11,935	30,659	9,353
	Private capital	122,615	6,362	23,965	56,656	80,621	35,632
	Other	33,851	7,066	18,092	8,693	26,785	-

Source: MoLIT, 「Third Establishment Plan for a National Rail Network」, 2016

2. Electrification Project & Saemaul Train Introduction Case Analysis

2.1. Electrification Project Background

2.1.1. Electrification of Industrial Lines

- South Korea experienced a drastic change in the industrial structure through several five-year economic development plans developed from 1962.

- Industrial production increased drastically, and the passenger and freight traffic soared. Particularly, after the mid-1960s, difficulties in transporting freight such as coal, cement, cereals, and fertilizers became so serious as to block the economic growth.

- Thus, in order to cope with the sudden rise in the transport demand and the steep economic growth after the late 1960s, the railway authorities decided to aggressively pursue the electrification of the rail lines in the capital region (Gyeongin, Gyeongsu, and Gyeongwon Lines) and the industrial lines (Jungang, Taebaek, and Yeongdong Lines).

- Due to the drastic increase in the transport demand, the extension of valid lengths was considered originally, but based on the determination that the extension of valid lengths alone could not possibly solve the fundamental problems, the electrification of rails and their conversion into double track began to be examined.

- The most ideal way of increasing the transport capacities was to convert single track into double track, and the electrification was the second-best solution, but the conversion into double track had the demerit of requiring an enormous budget.

- Even in the case of Jungang Line, which had the most favorable terrains among the subject lines, the track condition was not good because it had 26 tunnels with a total length of 17.3 km and individual lengths longer than 200 m and they took up 8% of the entire route. Thus, the general opinion was that doubling the single track was impossible due to financial conditions, and because of this, the authorities embarked on the electrification.

2.1.2. Electrification of Passenger Rails

• As the Korean War entered into a truce in 1953, the population of Seoul began to rise so fast that it reached 3 million in the early 1970s and the population density became as high as 24,500명/km2 , making the city one of the most densely-populated cities in the world.

• Particularly due to the economic development plans executed from 1962, the passenger transport demand increased drastically along with a radical change in the industrial structure.

• Thus, the government tried to solve traffic problems by extending the roads, but there were limits in the road transport capacities in the densely-populated city, and environmental problems such as air pollution were generated.

• Therefore, new alternatives of rails were suggested to solve the traffic problems, and electric rails were proposed as promising alternatives in terms of mass transportation, safety, speed, comfort, accuracy and convenience.

• Particularly in the case of Gyeongbu (Seoul-Busan) Line, it had already been converted into double track completely in 1939. So, it was determined as the more efficient way of resolving the traffic problems to implement electrification projects rather than to enhance the rail carrying capacities by converting the lines into quadruple track, which costed a lot.

• Also, since electric rails were excellent in environment friendliness and energy efficiency when compared with diesel locomotives, the idea of utilizing electric rails was suggested as a new means of transporting passengers.

• Thus, the Seoul-Suwon section of Gyeongbu Line was completely electrified in August 1974, and the line was opened first by importing rolling stock from Nippon Train Manufacturing Company of Japan (Hitachi Manufacturing Plant).

2.2. Electrification Project Chronology & Funding

2.2.1. Chronology

• Mar. 1961: Established an electrification plan after creating Electrification Dept. in the Ministry of Transportation

- Dec. 1961: Dispatched technical personnel for electrification to Japan and France and received technology transfer from them.
- Sep. 1962: Conducted technical investigations for the electrification of Gyeongin Line.
- Sep. 1963: Founded Korea National Railroad, created Electrification Dept. in it, and drafted an electrification plan.
- Jun. 1964: Conducted investigations and surveying for the electrification of Jungang Line.
- Oct. 1964: Conducted investigations and surveying for the electrification of Taebaek Line.
- May 1966: Created Electricity Dept. in Railroad Construction Bureau.
- May 1967: Designated the electrification of Jungang Line as a pledged project.
- Nov. 1967: A Japanese technical team conducted technical investigations for the electrification of Jungang and Taebaek Lines.
- May 1968: The President instructed the implementation of electrification projects for industrial lines (Jungang, Yeongdong and Taebaek Lines) and earmarked a budget of KRW 50 million from the national treasury for the electrification, and the Jungang Line electrification project was commenced.
- Jan. 1969: Created Electrification Dept. in Railway Construction Bureau.
- Feb. 1969: Created the 1st and 2nd Electrification Construction Offices (in Yangpyeong and Jaecheon).
- Sep. 1969: Embarked on the Jungang Electrification Project.
- Dec. 1969: Established an agreement on the electrification of industrial lines.
- Jan. 1971: Commenced the Taebaek Line Electrification Project.
- Jun. 1972: Completed a 10.7 km test track between Jeungsan and Gohan of Taebaek Line.
- Dec. 1972: Started the Yeongdong Line Electrification Project.
- Jun. 1973: Opened the 155.2 km Cheongnyangni~Jaecheon section of Jungang Line.
- Jun. 1974: Opened the 80.1 km Jaecheon~Gohan section of Taebaek Line.
- Dec. 1975: Opened the Gohan~Baeksan and Cheoram~Bukpyeong sections (85.5 km) of Taebaek Line.
- Even after that, the electrification of the national rail network was continually executed so that the electrification rate, which was only 11.8% in 1985, reached 70.4% in 2015.

2.2.2. Funding

- For the electrification of Jungang and Taebaek Lines, a total of KRW 50.2 billion was spent.
  - Of the project cost, USD 89 million (KRW about 43.5 billion) was supplied as a loan from the European 50C/S Group (a loan consortium of Germany, UK, France, Switzerland, and Belgium).
  - Also, the loan consortium provided electric locomotives, major materials and technologies, and the design and construction were carried out with the technical guidance from the consortium.

• The national budget for the electrification project in 1968 was appropriated as KRW 50 million for the first time and was spent on the construction of buildings of 650 ㎡, three substations and 500 catenary wires and the land acquisition of 14,700 ㎡

Table 80 | Electrification Project Costs by Line

Category	Total (KRW Mill.)	Domestic Fund (KRW Mill.)	Foreign Fund (USD 1,000)	Remarks
Jungang Line	9,400	2,700	14,000	
Taebaek Line	5,100	1,600	7,000	
Yeongdong Line	6,200	2,400	8,000	
Electric Locomotives	29,500	-	60,000	90 cars (5,300 HP)
Total	50,200	6,700	89,000	KRW 157 mill./km

Note: The cost is for electrification facilities and exclusive of architectural costs for tunnel reinforcement and extension of the valid length of stations.
Source: KRNA, 「Korea Rail Construction 100-year History」, 2005

Table 81 | Breakdown of Jungang & Taebaek Line Electrification Projects

Category	Total (KRW Mill.)	Domestic Fund (KRW Mill.)	Foreign Fund (USD 1,000)	Remarks
Power Transmission & Substation Facilities	3,149	683	5,231	11 substations 10 section posts 11 aux. section posts Command centers (Mangwoo, Yangju) Transmission line: 124km
Catenary	10,569	3,549	14,469	Catenary length: 504km Elec. poles: 11,130 nos. Beams: 1,446 nos.
Telecomm. System	4,124	1,690	5,018	Shield cable: 320km Carrier terminals: 13 nos. Protection of power induction: 1 lot
Signaling System	2,858	778	4,282	C.TCs: 32 nos. (Jungang Line) ATSs: 316 nos. Type-1 relay interlocking: 64 nos.
Elec. Locomotives	29,500	-	60,000	90 locomotives
Total	50,200	6,700	89,000	KRW 157 mill./km

Note: This cost is for electrification facilities and is exclusive of architectural costs for tunnel reinforcement and extension of the valid length of stations.
Source: KRNA, 「Korea Rail Construction 100-year History」, 2005

• Since then, the electrification projects have been implemented chiefly with the budget of the Korean government.

2.3. Electrification Project Trend & Plan

2.3.1. Electrification Project Trend

• The electrification projects of South Korea have been continuously executed since 1970s, and the electrification rate as of 2015 is 70.4%.

Table 82 | Rail Electrification Rate Trend of South Korea

Year	Rail Length (km)	Electric Rail Length (km)	Electrification Rate (%)
1985	3,126.3	368.9	11.8
1990	3,091.1	522.4	16.9
1995	3,107.8	556.3	17.9
2000	3,124.8	668.7	21.4
2005	3,394.1	1,669.9	49.2
2010	3,554.6	2,147.0	60.4
2015	3,873.7	2,727.1	70.4

Source: National statistics portal

• As a result of comparing major countries' rail electrification rates, one can see that the rail electrification rate of South Korea or 66.97% is relatively high when compared with that of those countries.

Table 83 | Comparison of Major Countries' Electrification Rates

Country (Country code)	2010			2011		
	Rail length (km)	Electrified length (km)	Electrification rate	Rail length (km)	Electrified length (km)	Electrification rate
South Korea (KR)	3,554	2,147	60.41%	3,637	2,436	66.97%
China (CN)	66,239	32,717	49.39%	66,050	34,330	51.98%
Japan (JP)	20,141	12,391	61.52%	20,133	12,383	61.51%
France (FR)	29,841	15,635	52.39%	30,013	15,768	52.54%
Germany (DE)	33,707	19,819	58.80%	33,570	19,826	59.06%
Spain (ES)	15,543	9,267	59.62%	15,633	9,441	60.39%

Source: UIC, 「International Railway Statistics」

• As of 2014, all the rails in South Korea except conventional rails are being operated with double track, and the electrification rate of conventional rails is slightly lower than the total average.

Table 84 | Rail Lengths by Type

Rail Type	Rail Length (Km)	Double-tracking Rate (%)	Electrification Rate (%)
Total	3,729.0	57.6	69.6
High-speed rail	368.5	100.0	100.0
Conventional rail	3,241.7	51.2	65.0
Metropolitan rail	58.1	100.0	100.0
Airport rail	61.0	100.0	100.0

Source: MoLIT, 「Third Establishment Plan for a National Rail Network」, 2016

2.3.2 Electrification Project Investm ent Plan

• As mentioned earlier, conventional rails are being operated with electrified and non-electrified rails mixed, resulting in low efficiency of train operation.

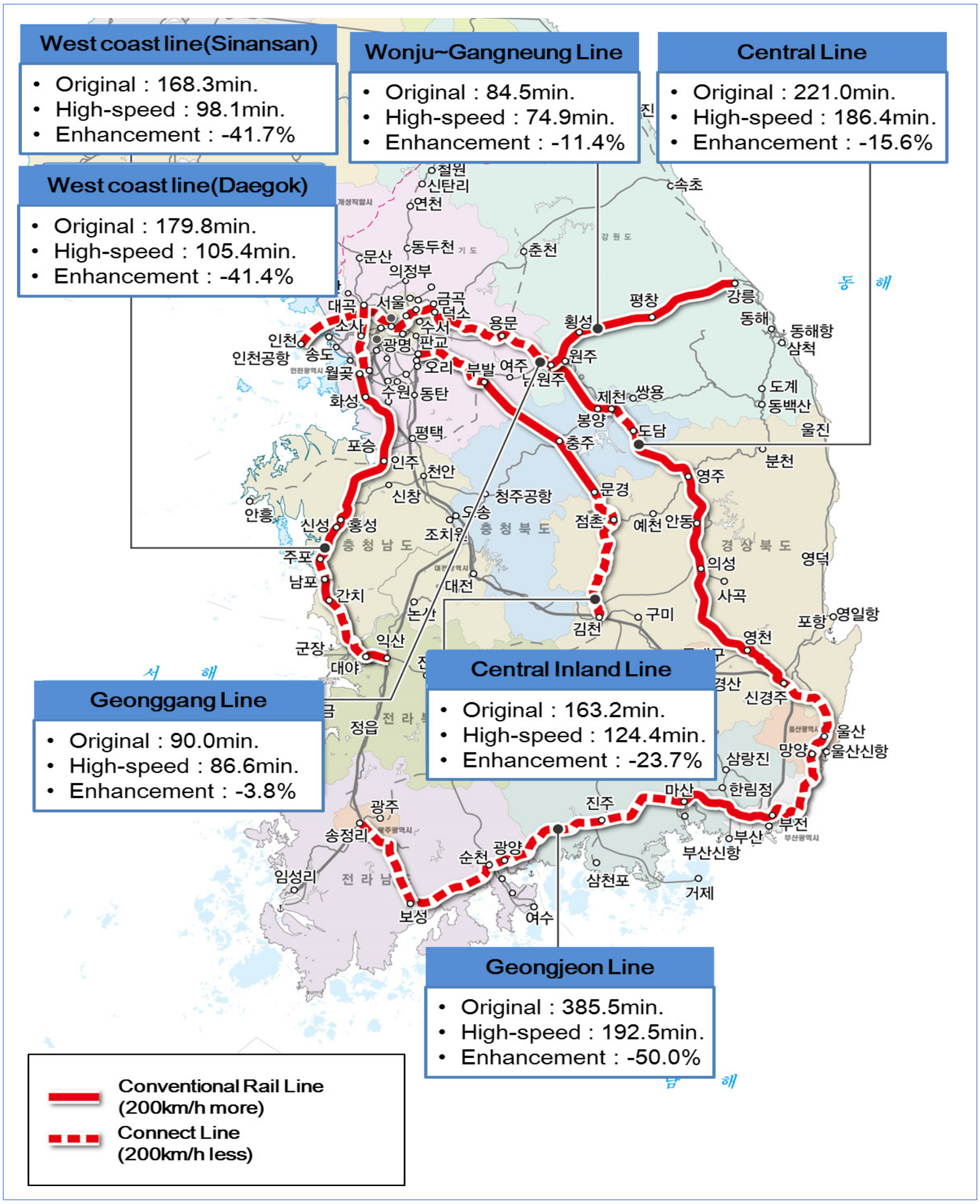
• Thus, in the 3rd national rail network plan, an electrification project for non-electrified existing lines is being developed, and approximately KRW 7 trillion is going to be invested on nine projects such as the creation of electrified lines.

Table 85 | South Korea's Investment Plan for Electrification Projects

Line Name	Project Section	Electrified track Type	Length (km)	Total Project Cost (KRW 100 mill.)
Jungang	Yongsan~Cheongnyangni~ Mangwoo (private financing)	Quadruple track	17.3	13,280
Suseo-Gwanju	Suseo~Gwangju (private financing)	Double track	19.2	8,935
Gyeongjeon	Jinju~Gwangyang	Electrified	57.0	1,524
	Gwangju Songjeong~Suncheon	Single track	116.5	20,304
Janghang	Sinchang~Daeya	Double track	121.6	7,927
Donghae	Pohang~Donghae	Electrified	178.7	2,410
Mungyeong-Gyeongbuk	Mungyeong~Jeomchon~Gimcheon (private financing)	Single track	73.0	13,714
Gyeongjeon	Boseong~Mokpo	Single track	82.5	1,702
Gyeongbuk	Jeomchon~Yeongju	Single track	56.0	980
Total			721.8	70,876

Source: MoLIT, 「Third Establishment Plan for a National Rail Network」, 2016

• On the other hand, major corridors along which high-speed rails are not currently being operated will be electrified, and the conventional rail lines will be made more competitive by mobilizing EMU-250 trains, which are semi-high-speed vehicles.



2.4. Electrification Project Effect

2.4.1. Travel Time Reduction

- Due to the electrification, travel time by Jungang Line reduced by about 3.5 hours from 7 hours 50 min. to 4 hours 20 min., and travel time by Taebaek Line reduced by about 40 min. from 3 hours 20 min. to 2 hours 40 min.

- Travel time by Yeongdong Line reduced by about 40 min. from 2 hours 40 min. to 1 hour 40 min. Travel time between Incheon and Seongbuk by the metro system in the capital region reduced by about 40 min. from 2 hours to about 1 hour 20 min.

Table 86 | Comparison of Travel Time before & after the Electrification of Industrial Lines

Category	Jungang Line (Cheongnyangni~Jecheon section, 155.2㎞)	Jungang Line (Jecheon~Yeongju section, 64.0㎞)	Taebaek Line (Jecheon~Gohan section, 80.1㎞)	Capital Region Metro (Incheon~Seongbuk section, 52.1㎞)	Yeongdong Line (Yeongju~Cheoram section, 87.0㎞)
Before electrification	6 : 00	1 : 50	3 : 20	2 : 00	2 : 40
After electrification	4 : 00	1 : 20	2 : 40	1 : 21	1 : 40
Time saving	2 : 00	0 : 30	0 : 40	0 : 39	0 : 40
Time saving effect (%)	33	27	20	32	25

Source: MoLIT, 「Rail Statistics」, 2016

- With the introduction of Saemaul Trains, which is the first passenger rail, travel time between Seoul and Busan was reduced.

- With the introduction of Saemaul Trains, travel time between Seoul and Busan reduced from 6 hours 40 min. to 4 hours 50 min. After that, when the vehicles for Saemaul Trains were upgraded, the travel time reduced to 4 hours 10 min.

Table 87 | Yearly Changes in Speed & Travel Time by Passenger Rails in South Korea (based on Seoul-Busan section)

Year	Train Name	Motive power	Travel time	Average speed (km/h)	Max. speed (km/h)
1946	Haebangja	Steam	10 hours 40 min.	41	70
1955	Tongil	Steam	9 hours	50	80
1957	Tongil	Diesel	7 hours 40 min.	62	80
1960	Mugunghwa	Diesel	6 hours 40 min.	67	95
1969	Gwangwang[1)]	Electric	4 hours 50 min.	92	110
1986	Saemaul[2)]	Electric	4 hours 10 min.	107	140
2004	KTX	Electric	2 hours 34 min.	159	300

Note 1: Gwangwang is the first passenger line in South Korea and the trains were imported from Japan. The name was changed into Saemaul in 1974.
Note 2: This was developed by upgrading the model of Gwangwang in preparation for the Asian Games and the 1988 Seoul Olympic. The shape was changed into a streamlined one. It was the first train developed and manufactured by South Korean technology.
Source 1: Yong-sang LEE, 「History and Development of Korean Railways」, 2011
Source 2: KRNA, 「Korea Rail Construction 100-year History」, 2005

2.4.2. Increase in Traction Performance

- The traction performance of diesel locomotives that had been operated before the electrification ranged from 800HP to 2,500HP, but due to the introduction of electric locomotives, it rose up to 5,200HP.

- Due to the difference in traction performance, the speed in a section with a gradient of 10‰ increased from 15 ~17km/h by diesel locomotives to 50km/h by electric locomotives, and the speed in a section with 25‰, from 13~15km/h to 47km/h.

Table 88 | Comparison of Speeds by Gradient between Diesel and Electric Locomotives

Gradient	Traction Weight	Elec. Locomotives (km/h)	Diesel Locomotives (km/h)
10‰	1,740 tons (40 cars)	50	15~17
25‰	1,740 tons (40 cars)	47	13~15
30‰	1,740 tons (40 cars)	44	-

Source: KRNA, 「Korea Rail Construction 100-year History」, 2005

• Due to the difference in traction performance between diesel and electric locomotives, tow has been increased as follows:

Table 89 | Comparison of tow of Industrial Lines before and after the Electrification

Line	Section	1968 (Diesel)			1971 (Elec)			1981 (Elec)		
		No. operation	No. tow	Total	No. operation	No. tow	Total	No. operation	No. tow	Total
Jungang	Cheongnyangngi-Jecheon	24	40	960	40	40	1,600	50	40	2,000
	Jecheon-Yeongju	19	40	760	30	40	1,200	34	40	1,360
Taebaek	Jecheon-Yeongwol	18	26	468	36	35	1,260	40	35	1,400
	Yeongwol-Yemi	20	26	520	33	35	1,155	34	35	1,190
	Yemi-Jeugsan	13	20	260	31	30	930	31	30	930
Total		94	152	2,968	170	180	6,145	189	180	6,880

Source: KRNA, 「Korea Rail Construction 100-year History」, 2005

• The increase in tractive capacities of the industrial lines naturally led to the increase in track capacities, and in the case of Jungang Line, the track capacities rose to 32%~53%.

Table 90 | Increase in Track Capacities before and after the Electrification

Unit: Times/day

Category	Cheongnyangngi~Jecheon	Jecheon~Yeongju	Jecheon~Gohan	Guro~Incheon
Before the electrification	34	33	17	39
After the electrification	45	45	26	56
Variance	32% up	32% up	53% up	44% up

Source: Korea National Railroad, 「Master Plan for Electric Rail Network Establishment」, 2002

2.4.3. Decrease in Operating Costs

• To verify the effect after the railway electrification in Japan, the motive power consumption per million km and the motive power costs per million km were studied and analyzed. As a result, it turned out that about 28.7% of the transportation expenses were saved after the electrification.

Table 91 | Comparison of Power Costs of Diesel vs. Elec Locomotives

Category	Elec			Diesel			Remarks
Vehicle type	EL	EC	Total	DL	DC	Total	
million km	13,796	10,043	23,839	2,823	3,028	5,851	
Power consumption (kWh, kl)	2,281	2,281	4,950	2,286	424	710	
Power cost (Mill. yen)	12,893	2,671	27,991	3,869	5,737	9,606	
power cost (yen)	0.94	1.50	1.17	1.37	1.89	1.64	28.7% down

Source: Korea National Railroad, 「Master Plan for Electric Rail Network Establishment」, 2002

• South Korea compared the investment costs and annual operating costs before and after electrification of industrial lines, analyzing the operating cost saving effect.

• As a result, the investment cost increased by the electrification was about KRW 1.56 million, and the operating cost saving was about KRW 330 million. Thus, it was analyzed that the investment cost would be paid back in 5~6 years and economic income would be generated.
  - The cost estimation is based on 60 locomotives (new ones) for electric railways and on 33 locomotives of 2,500 HP (the required number of cars except existing ones) and 92 locomotives of 1,800 HP (new ones).

Table 92 | Comparison of Investment Costs & Annual Operating Costs based on the Operation of Elec. vs. Diesel Locomotives

Unit: KRW Mill.

Category		Elec (A)	Diesel (B)	A-B
Investment cost	Power car	4,914	7,073	-2,159
	Wayside system (catenary)	3,720	-	3,720
	Signaling & telecom. facilities	949	949	0
	Total	9,583	8,022	1,561
Annual expenses	Power cost	812	1022	-210
	Maintenance cost	0.9	55	-54
	R/S repair cost	168	332	-164
	Wayside system repair cost	54	-	54
	Depreciation cost	284	333	-49
	Annual interest for invested amount	575	481	93
	Total	1,895	2,225	-330

Source: Korea National Railroad, 「Master Plan for Electric Rail Network Establishment」, 2002

- Electric vehicles are known as being efficient in terms of maintenance costs when compared with diesel vehicles.
  - As electric locomotives require a smaller number of inspectors due to their simple body structure, their maintenance cost is low.
  - Electric locomotives require a higher procurement cost than diesel locomotives. If, however, diesel locomotives are replaced with electric ones, the maintenance cost of about KRW 140 million per car per year will be saved.
  - If diesel power cars are replaced with electric ones, the maintenance cost of about KRW 60 million per car per year will be saved.

Table 93 | Comparison of the Procurement Costs and Maintenance Costs of Electric vs. Diesel vehicles

Unit: KRW 100 mill.

Vehicle	Price	Maintenance cost	Annual maintenance cost	Variance
Diesel locomotives	34	60.93 (25 yrs)	2.44	-
Electric locomotives	41	40.44 (40 yrs)	1.01	-57.8%
Diesel power cars	13	17.6 (20 yrs)	0.88	-
Electric power cars	10.23	6.71 (25 yrs)	0.27	-57.3%

Source: KRRI, 「A Study on Development of Railway Electrification Effect Measuring Indicators」, 2006

2.4.4. Reduction in the Discharge of Pollutant Substances

- As electric vehicles are not internal-combustion engines, they do not generate CO2, a pollutant substance, and thus are efficient in the environmental aspect when compared with diesel vehicles, sedans and trucks.

- The following table shows the emissions of CO2 by mode of transportation. If cargoes are carried by sedan, the emission of CO2 is about 99 times that of electric railways.

Table 94 | Comparison of the Emissions of CO2 by Mode in Case of Freight Transportation

Unit: g-C/ton-km

Rail (Elec.)	Car (Truck)		Marine transport	Airplane	Remarks
General	for business	for non-business			
6	180	599	10	420	Based on the same traffic volume

Source: Korea National Railroad, 「Master Plan for Electric Rail Network Establishment」, 2002

- The emission of CO2 by electric locomotives is equal to about 55% of that of diesel ones.
  - In 2005, diesel and electric locomotives discharged 19.0 kg and 10.6 kg of CO2, respectively, while they were running 1 km.

Table 95 | Emission of CO2 by Elec. & Diesel Locos While Carrying Passengers (as of 2005)

Unit: kg_CO_2 /km

Loco Type	Average in 2005	Yeongdong Line (193.6km; in 2005)
Diesel	19.0	26.1
Electric	10.6	14.6

Source: KRRI, 「A Study on Development of Railway Electrification Effect Measuring Indicators」, 2006

- As a result of comparing the emission of CO2 by sedans with other modes when they are carrying the same number of passengers, sedans discharged about 9 times more than conventional rails.

Table 96 | Comparison of the Emission of CO2 by Mode of Transporting Passengers

Unit: g-C/person-km

Rails (Elec.)		Vehicles		Marine Transport	Airplane	Note
Conventional	High-speed	Bus	Sedan			
5	6	19	45	24	30	Based on the same traffic volume

Source: Korea National Railroad, 「Master Plan for Electric Rail Network Establishment」, 2002

2.5. Introduction & Development of Saemaul Trains

- Saemaul Trains are the first passenger trains in South Korea. They were imported from Japan in 1969 and ran for the first time on Gyeongbu Line. Their original name was Gwangwang.

- In 1975, Daewoo Heavy Industries, a South Korean company, succeeded in developing and producing them based on the design documents of the vehicles imported from Japan. Beginning from 1979, they were manufactured and supplied jointly by Daewoo Heavy Industries and Hyundai Precision Industry.

- Around this time, the vehicle name was changed from Gwangwang to Saemaul.

- After succeeding in the localization of electric passenger trains, the vehicles upgraded from the model of Gwangwang were produced successfully in preparation for the 1986 Asian Games and the 1988 Seoul Olympic.

  - As the shape of the vehicle changed from a rectangular shape to a streamlined shape, its operating speed increased and the service level of the passenger coaches was improved.

- Due to the operation of Saemaul Trains, the travel time between Seoul and Busan reduced by 2 hours 40 min. from 6 hours 40 min. to 4 hours 10 min. (initially, 4 hours 50 min.).

- Saemaul Trains had been upgraded twice in their model.

2.5.1. Gwangwang Trains in the Initial Stage (Introduced in 1969)

- The trains had a rectangular shape and were introduced in 1969, 1975, 1979, 1981 and 1982, and until 1975, the whole quantities were imported from Japan.

- They are the first electric passenger cars in South Korea. In 1975, they could be manufactured by the domestic technology.

- As passenger cars of streamlined shape for a higher level of services were introduced in 1987, most of them were used degraded into the VIP rooms in Mugunghwa Trains. After that, they were used temporarily in excursion trains in Jeongseon, and currently are obsolete.

2.5.2. Saemaul Trains of Streamlined Shape (Introduced in 1986)

- Saemaul Trains were imported twice in 1986 and 1987 for a higher level of services in preparation for the 1986 Asian Games and the 1988 Seoul Olympic.

- With the introduction of the trains of streamlined shape, the travel time between Seoul and Busan reduced from 4 hours 50 min. to 4 hours 10 min.

- The doors for the passenger coaches were changed into automatic ones. Their waste disposing method was changed from splashing type to storing type.

2.5.3. Saemaul Tains of Long Shape (Introduced in 1990)

- These were developed by upgrading the streamline-shaped Saemaul Trains and were introduced four times in 1990, 1991, 1999 and 2001.

- They were drastically upgraded in indoor specifications rather than in vehicle performance. The material of the automatic doors for the passenger coaches was changed from stainless steel to the material which was the same as that of the interior walls.

- The toilets were changed from squat type to seat type. By separating the basins from the toilets, sanitation was improved.

- Above the doors for passenger coaches were LED boards, which showed information on the stops, destinations, train nos., etc.

- For the seats, calf props were installed so as to provide the best quality services in South Korea.

3. KTX Introduction & Operation Cases & Effects Analysis

3.1. KTX Introduction & Operation Case Studies

3.1.1. KTX Introduction Background

1) Necessity of Drastic Transportation Measures

- To support the five-year national economic plan developed in the 1960s, South Korea made a push to implement polices that bolster transportation capabilities centering on expressways for the purposes of constructing the social overhead capital (SOC) and foster key industries based on the development of national economy.
- Thus, road infrastructures such as Gyeongbu and Gyeongin Expressways were constructed, increasing the nos. of the expressways and national roads constructed. However, less investment was made on the construction of railways.

- Of the transportation investments made since 1970, road construction took the first place 50% while railway construction remained nill if the railways for harbors and inlet tracks for industrial complexes are excluded. Only double tracks for key rail lines, electrification of railways and alignment improvement of some sections were carried out.

- In the 1980s, transportation facilities reached saturation point due to the rapid industrialization in the country, and there were limits in coping with the travel demand only with roads.

Table 97 | Passenger Traffic Shares of Different Transportation Means along Gyeongbu Line(in 1988)

Unit : 1,000 persons/day

Category	Saemaul	Mugunghwa & Tongil	Bidoolgy	Car	Bus	Total
Nationwide	15	207	87	1,088	2,606	4,009
Gyeongbu Corridor	13	121	50	947	1,480	2,617
Share (%)	86.7	58.5	57.5	87	56.8	65.3

Note: Saemaul, Mugunghwa, Tongil and Bidoolgy are Korean conventional trains in the order of operating speeds (Saemaul is the fastest among them).
Source: Korea Transport Institute, 「Environmental Impact Assessment Report on Gyeongbu HSR」, 1992

- Along the Gyeongbu corridor, 65.8% of the Korean population and 73.7% of the GDP were concentrated, and 66% of the total passengers and 70% of the total cargoes in the country were being carried.
- In 38% of the entire Gyeongbu Expressway, transporting difficulties were taking place due to traffic congestions.

Table 98 | Freight Traffic Shares along Gyeongbu Line (in 1988)

Unit : 1,000 tons/day

Category	Rail	Road	Total
Nationwide	137	652	789
Gyeongbu Line	63	469	532
Share (%)	46	72	67

Source: Korea Transport Institute, 「Environmental Impact Assessment Report on Gyeongbu HSR」, 1992

• Moreover, as the travel demand growth rates at that time were 5.3% for passengers and 4.7% for freight and so the logistical difficulties were expected to become worse, special measures had to be devised.

2) Recommendation by Domestic & Overseas Research Institutes to Construct a High-speed Rail

• When the country discussed borrowings for rails from IBRD in 1973, a survey group from SNCF and JARTS researched the transportation condition between Seoul and Busan in 1974 upon the World Bank's request.

• At that time, South Korea was just completing the industrial and metropolitan electric rail projects, and the examiners in Japan and France proposed the construction of a high-speed rail with their prospect that the existing Gyeongbu Line would be saturated in the 1980s.

• Almost at the same time, a group of professors hired to evaluate the South Korean government's policies proposed a project similar to the project by the Japanese and French survey groups, as measures to increase the long-term transportation capacities of the Gyeongbu (Seoul-Busan) railway.

• And in the 1980s, Korea Advanced Institute of Science & Technology (KAIST) recommended the construction of a new railway along the Gyeongbu corridor by preparing a study report on the ways of optimizing heavy freight transportation systems and transport investments, which consequently triggered a full discussion on a high-speed rail.

3.1.2. KTX Introduction Process

1) Feasibility Studies

a) Performance of Feasibility Studies

• The feasibility studies were carried out in two phases from March 1983 to November 1984.
- In Phase 1, the necessity of long-term transport investments was reviewed, and in Phase 2, the feasibility of a high-speed rail system was analyzed.
- Phase 1: Considering the future travel demand of the Seoul-Busan corridor, investment alternatives for the construction of a HSR, the upgrading of the existing Gyeongbu Line and road construction were proposed (Feb. to Aug. 1983).
- Phase 2: Economic, financial and technical studies were conducted with regard to the alternative of constructing a HSR.

• During the feasibility study phase 1, the three alternatives were chiefly analyzed, which can be outlined as follows:
- Alternative 1: Focusing on the expansion of the expressways and the phased improvement of the existing Gyeongbu railway;
- Alternative 2: Aiming at making the railway and the expressway compete with each other by creating a HSR and expanding the required zone on the expressway between Seoul and Busan; and
- Alternative 3: Concentrating on railways by creating a HSR between Seoul and Busan, promoting the policies of increasing the use of the HSR, minimizing the investment on roads and improving other transportation means and enhancing the interface with them.

Survey Results

• A close review of the three alternatives showed that Alternative 3, the railway plan, was better than the others, considering South Korea's transportation circumstances.

• According to the conclusion that the alternative of constructing a HSR was the best choice from a long-term perspective, detailed economic and financial analyses were conducted for the construction of a high-speed rail, and the result was that it was feasible both economically and financially.

2) Determining Technical-survey Policies

- After the feasibility studies, the need to construct a HSR quickly expanded and was incorporated into the Fifth Five-year Economic and Social Development Plan (1982-1986). Thus, the construction of Gyeongbu HSR was to be commenced within that period.

- The ever-increasing demand for the establishment of social-overhead-capital infrastructure in preparation for the 1988 Seoul Olympics, however, resulted in the conclusion that it would be practically impossible to secure funds for the construction of a HSR. Consequently, the project was postponed.

- Afterwards, the construction of a HSR was specified in the Sixth Five-Year Economic and Social Development Plan. Accordingly, a technical survey on the construction project was to be carried out, leading to a positive preparation for the project.

- In determining the policy to execute technical surveys, the following issues were discussed:
  - First, people's concern that it was premature to construct a HSR
  - There was the argument that the speed of the existing trains, driven by diesel locomotives, could be increased by up to 200 km/h only by improving the alignment and gradients of the existing Gyeongbu Line and changing the sections expected to become congested into double track. The main point of this argument was that the mid- and long-term demand could be handled and the travel time could be decreased even without promoting the HSR, which would require additional lines.
  - Second, rather than a wheel loader, a magnetic-levitation train, the next-generation type, should be introduced.
  - There was the argument that considering the progress of the development of railway technologies, the magnetic-levitation type, which does not entail the issues of noise and dusting, will soon replace the wheel loader type, and thus, the construction of the latter type will become meaningless.
  - Third, if a high-speed rail is constructed along the Seoul-Busan corridor, the problems of the population and industrialization concentrated along the corridor would worsen.
  - There was the argument that due to the reduction of travel time, the population and industrialization would be concentrated along the Seoul-Busan corridor, hampering a balanced development of the country.

- Although such arguments were made, it was determined to proceed with the technical surveys for the construction of a high-speed rail such as today's on the bases that the Gyeongbu transport network, which had already reached its limits, could pose a critical obstacle to the national economy, that a balanced development of different regions could be achieved by the commercial development of HSR station vicinity areas, and that the practicality of technologies, safety and operating efficiency could be enhanced.

3) Execution of the Technical Survey

- On 15 July 1989, two months after the decision was made to incorporate the technical-survey policy for the construction of Gyeongbu HSR in the 6th Five-year Economic and Social Development Plan, the technical survey was commenced.

- Conducted for 3 years until February 1991, the technical survey aimed to study all the technical aspects of the construction of a HSR between Seoul and Busan. Introduction of a high-speed rail requires a three-phased plan: the master planning and design phase, the rolling stock system selection and acquisition phase, and the detail design phase for the construction. The technical survey focused on the first phase.

a) Basic direction of the construction standard

- The design standard of the HSR was defined in a way that would make it suit South Korea's technology by observing the design standards of foreign countries and UIC. The following table shows the construction standard considering the rail condition of South Korea and according to it, proposed conditions for the selection of vehicle types were presented.

Table 99 | Basic Direction of the Construction Standard

No.	Design Standard
1	A railway on which diesel locomotives can run by considering the linkage with the existing railway
2	A railway that will allow interoperability with the South-North Koreas and the Eurasian railway through China in the future
3	A railway that will allow future speed-up by considering the global trend of the high-speed rail technological development
4	A railway on which the rolling stock from any of Japan, France, and Germany can run

b) Basic direction of the vehicle codes

- During the technical survey, the max. speed of the vehicles on Gyeongbu HSR was set at 300 km/h because it was determined that this speed was economical and efficient if there were 2~4 stations in the 409 km zone between Seoul and Busan. Thus, the maximum operating speed of the high-speed rail systems was determined to be 300 km/h.

- Moreover, the plan was to operate localized rolling stock after the technology transfer of one of the three vehicles already developed. The top speed of the HSR systems that were already being operated was 300 km/h.

- Taking into consideration the energy consumption, maintenance, and ride comfort level while ensuring the trains run at their top speed and safely, the HSR system observed the construction code that ensured the construction of a rail appropriate for the design speed of 350 km/h.

- To improve the rolling stock technology of South Korea, the rolling stock was to be selected from the vehicles types of Japan, France or Germany, which could transfer their technology to the country for the localization of the rolling stock.

- Besides, the vehicle to be chosen should pose no or few problems when connected to the existing rail, and should be proper for mass transportation at high speed in South Korea, where the population density is very high.

c) Project implementation direction

- Civil engineering, track works and building construction were to be carried out utilizing South Korean technologies while foreign technologies would be introduced as core ones such as high-speed rolling stock, train control, catenary, and train radio system, which had yet to be developed in South Korea. Through technology transfer and domestic production, however, it was expected that these technologies would be acquired in the future.

d) Selecting the route

- The criteria for route selection were (in descending order of priority) the top speed of the train, the location of the stations, environmental conditions, natural conditions, the level of construction difficulty, maintenance, alignment conditions and economic performance.

- As a result of the route analysis, the following route plans were proposed:

- Two issues were chiefly debated on while selecting the route:
  - First, whether to make the route straight and minimize the intermediate stations or to maximize the travel demand and add intermediate stations while lengthening the route; and
  - Second, whether to add Miryang Station and whether to stop at Gyeongju Station.

- Considering the scope of the HSR construction beneficiary areas and the issues associated with the construction technologies resulting from the economic-performance analysis, Alternative 8 was selected in the technical survey in 1990.

Table 100 | Route Analysis Outcomes

No.	Alternative
①	Seoul~Daejeon~Daegu~Busan (Jungbu Route, two intermediate stations)
②	Seoul~Cheonan~Daejeon~Daegu~Busan (Jungbu Route, three intermediate stations)
③	Seoul~Daejeon~Daegu~Ulsan~Busan (Dongbu Route, three intermediate stations)
④	Seoul~Cheonan~Daejeon~Daegu~Mirayng~Busan (Jungbu Route, four intermediate stations)
⑤	Seoul~Cheonan~Daejeon~Daegu~Ulsan~Busan (Dongbu Route, four intermediate stations)
⑥	Seoul~Cheonan~Daejeon~Gimcheon~Daegu~Busan (Jungbu Route, four intermediate stations)
⑦	Seoul~Cheonan~Daejeon~Daegu~Gyeongju~Busan (Dongbu Route, four intermediate stations)
⑧	Seoul~Cheonan~Daejeon~Daegu~Gyeongju~Busan (in tandem with the Donghaenambu Route Double-track Project)

Source: Nam-tae Hur, "Impact of the KTX Service Quality & Customers' Satisfaction on Their Intention to Re-use It: Centering on the KTX Users of New Gyeongju Station", 2012

4) Project Planning

a) Initial project plan

Table 101 | Initial Project Plan

Category	Description
Route length	Seoul~Busan 409km (tunnels: 42%)
Maximum design speed	350km/h
Travel time	90 min. for the direct operation (101 min. while stopping at two stations)
Project period	1992~1998
Construction cost	KRW 5.8462 trillion (KRW 1.2144 trillion for rolling stock procurement, as of 1989)
Usage demand	218,000 passengers/day
Financial stability	Annual surplus three years after the opening; and cumulative surplus ten years after the opening
Route	Seoul-Cheonan-Daejeon-Daegu-Gyeongju-Busan (4 intermediate stations)

Source: Ministry of Strategy & Finance, "Economic Development Experience Modularization Project 2012: South Korea's Private Investment Projects", 2013

- Based on the technical survey performed beginning in 1989, the master plan was established, and on 15 June 1990, based on the resolution of the third HSR & New International Airport Construction Promotion Committee, the master plan and route of the Gyeongbu HSR Project was determined and announced, as shown below.

b) Determination of the basic route

- Among the eight alternatives suggested in the technical survey, two alternatives—Alternative 1 (Seoul-Daejeon-Daegu-Busan) and Alternative 8 were short-listed.
  - Alt. 1 represented a straight route. While the running time was shorter, its tunnel length was longer due to the technology, and compared with the size of the investment, the beneficiary areas were limited.
  - Alt 8 represented high financial stability due to the improvement of the high-speed rail usage rate as it included Gyeongju, a major cultural- heritage and tourist zone,

and Ulsan and Pohang, two key industrial zones, but had the disadvantage of being a slightly diverting route.

• Finally, Alt. 8 was chosen as it could increase the HSR usage rate.

Table 102 | Comparison of Two Short-listed Route Alternatives in the Master Plan

Alt. Review		Alternative 1	Alternative 8
		Seoul-Daejeon-Daegu-Busan	Seoul-Cheonan-Daejeon-Daegu-Gyeongju-Busan
Topology	Distance	387km	409km (changed to 412km)
	Tunnel	48%	42%
Running time		Direct: 1 hour 26 minutes (two stops: 1 hour 37 minutes)	Direct: 1 hour 30 minutes (two stops: 1 hour 41 minutes)
Transport demand		192,000 passengers/day	218,000 passengers/day
Cost		KRW 4.4267 trillion	KRW 4.6318 trillion
Financial stability		Annual surplus: 5 years after opening Cumulative surplus: 13 after opening	Annual surplus: 3 years after opening Cumulative surplus: 10 after opening
Characteristics		Shortest-distance route Limited beneficiary regions considering the investment size	Will accommodate the Cheonan and Gyeongju tourists. Will improve the usage rate. Needs to divert a bit.

Note: KRW 1.2144 trillion for rolling stock procurement.
Source: Ministry of Strategy & Finance, "Economic Development Experience Modularization Project 2012: South Korea's Private Investment Projects", 2013

c) Station locations

• While determining the stations, the locations were a delicate issue, where the local governments' and residents' interests were in sharp conflicts.

• Some local governments or residents did not want the route to go through their region due to the noise and environmental pollution potentially caused by the high-speed rail and the damage to cultural assets and the like that might be caused by the construction of the station and the route.

• Most of them, however, admitted that building a station in their area would promote the development of their local economy.

- Some key issues discussed when the locations of the stations were being selected were the formation of strong bases for developing new cities, conveniences in the use of the system (Seoul), the underground stations (Daejeon and Daegu) and their construction costs, and the effect of the construction on the cultural assets of that area (Gyeongju).

d) Design criteria

- One important task in constructing the country's first high-speed rail was the creation of design criteria.

- For this, the government referred to the UIC and the design criteria in other countries and sought the assistance of foreign and South Korean specialists and technical groups.

- It is worthy to note that in defining the goal of raising technical capacities through the project, the project chose a core-method code, which implied that the government decided to introduce only the core technologies from the advanced countries and to promote the use of the South Korean technologies for the other disciplines of the project, instead of the total-method code, based on which all the required technologies would be introduced from the advanced countries and South Korea would just manage the project.

5) Revisions of the Project Plan

- After the finalization of the master plan in 1990, the Gyeongbu HSR Project went through two major revisions. The main reasons were as follows:
  - First, after the construction of the test track, it was determined that the cost would rise significantly if the original route plan would be followed.
  - Second, there were consistent local complaints regarding the master plan.
  - Third, the unit price increased due to construction delays.

a) First revision of the project plan (June 1993)

- The initial cost of the project was KRW 5.8462 trillion, based on the constant market price from 1989 to the early 1990s.

- But, this cost estimate was based on the method of adding extra cost by a fixed rate to the existing rail construction cost because of the limited data available on the HSR construction, and thus, it was a little unreasonable from the onset.

- The roadbed construction was estimated at 1.4~1.5 times the unit cost of the existing line while the track construction was estimated at the same as that of the CWR (Continuously Welded Rail) laying for conventional rails. Also, the average unit price of TGV in France, Shinkansen in Japan or ICE in Germany was applied to the cost of the signaling and telecommunication systems.

• Therefore, more precise cost estimation had to be made when the actual construction had progressed to a certain extent. It was after 1993, when the Cheonan-Daejeon Test Track Section (57.2 km) was completed, that the realistic estimation of the construction cost became possible.

• Besides, the total length of the route rose more than 13 km from 409 km due to the bypassing route to Osong Station (4.9 km), the bypassing route due to the protection of cultural assets in Gyeongju (7.1 km), and the bypassing route due to the city plan in Yangsan District (1.3 km), all of which were not taken into consideration in the initial plan.

• Thus, considering the overall changes made to make up for the errors in the estimation, the incorporation of the market price hikes, and the extension of the route, the total project cost was estimated again at KRW 12.1743 trillion or more than twice the original cost estimate.
  - In the revised cost, 81.8% of the increase was from the changes made to make up for the errors in the estimation and the incorporation of the market price hikes while 18.2% was from route changes.

• Thus, design changes in some sections, reasonable adjustment of the construction time, and finalization of the station locations were performed in parallel in order to reduce the project cost when revising the project plan, and major modifications can be described as follows:
  - First, it was planned that the underground structures be constructed on the ground, and the existing structures be used to the maximum extent.
  - Thus, a revision was made to the underground area plan between Seoul and Susaek Stations and between Seoul and Gwangmyeong Stations.
  - By converting the underground zones of Daejeon and Daegu Station to the ground level, total investment cost reduced from KRW 12.1743 trillion to 10.7400 trillion.
  - To reduce the annual investment, which rose along with the increase of the total project cost, the construction period was extended for 3 more years, and therefore, the project was planned to be completed by 2001.

b) Second project revision (July 1998)

- After the initial revision of the plan in 1993, a further revision to the period and the cost was unavoidable.

- The government proposed a revision to the master plan in November 1997. While the concerned organizations were having talks, some significant changes took place in the environment of project implementation, such as the foreign-exchange crisis in 1997 and the establishment of a new government in 1998, resulting in a full modification of the project.

- In April 1998, after the instatement of a new government, a joint task force consisting of the Ministry of Construction and Transportation (MOCT), KTX and Korea National Railroad was organized to review the project cost and project period.

- Also, an assessment advisory committee comprising twenty-four specialists in economics, journalism, civil engineering, transportation, etc., performed a detailed analysis of the project, and after the feasibility studies and advisory meetings, the Social-Overhead-Capital (SOC) Construction Implementation Committee amended the master plan again in 1998.

- The second revision kept the framework of the original plan considering the consistency of the government policies and the transportation issues concerning the Gyeongbu corridor, and divided the whole zone into sections in the first and second phases to open them by phase in consideration of the then dire economic conditions.

  - The original plan was to open the whole zone in 2001, but it was determined that it would be impossible to do so by progressing in accordance with the investment plan.
  - Therefore, it was decided to construct a new high-speed rail in the Seoul-Daegu section as Phase 1 and utilize the existing rail between Daegu and Busan and open the whole route in 2004.
  - For Project Phase 2, it was decided to construct a new rail between Daegu and Busan and mine the downtown areas in Daejeon and Daegu to open them in 2010.

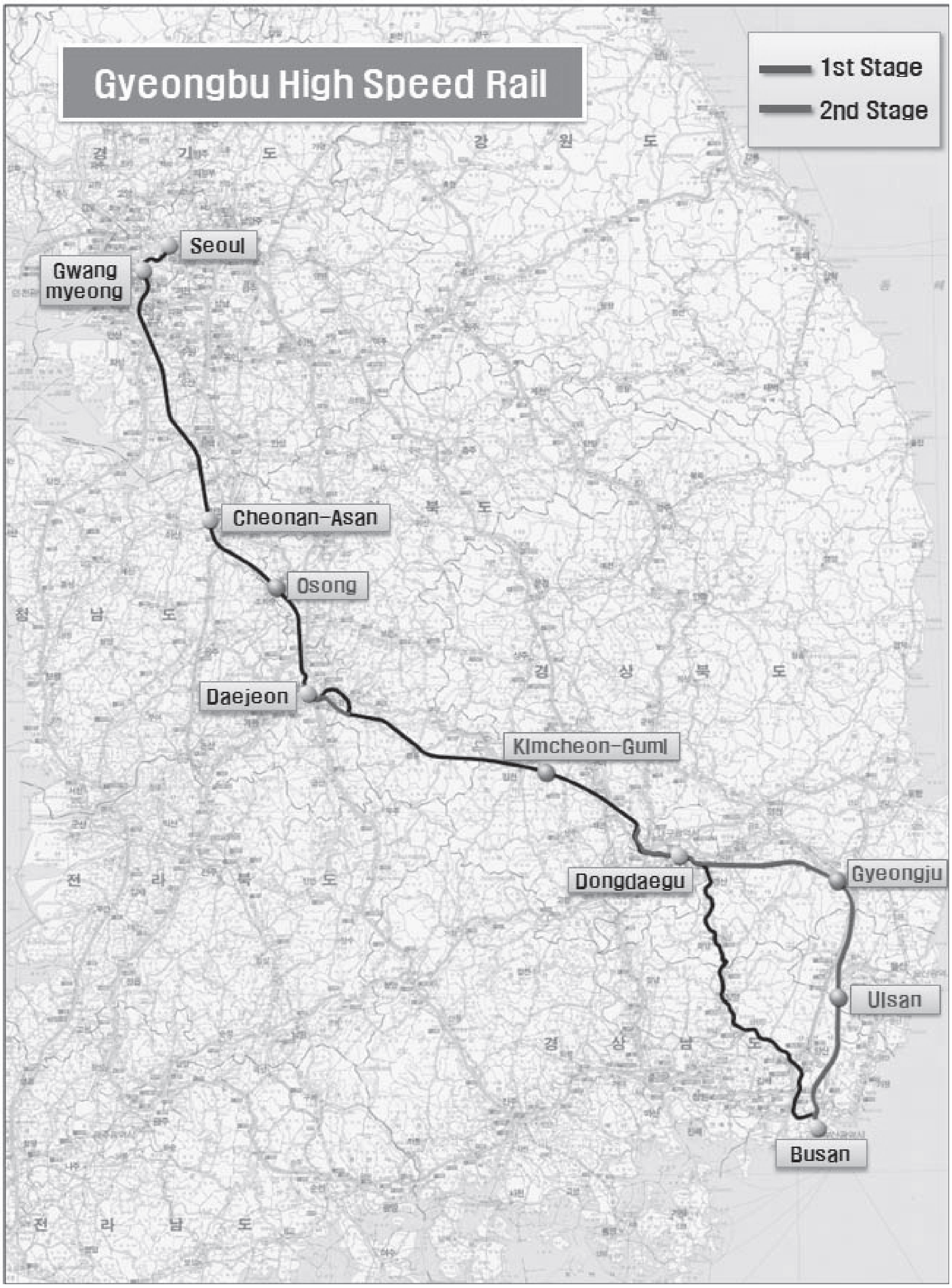
- As the project plan was revised twice, some of the civil complaints that had been raised until then were accepted.
  - The Gyeongje zone was finalized to be implemented in Phase 2 by diverting from the original route.
  - Also, the Sangni section was finalized to bypass the areas with unstable ground due to mines and to be implemented in Project Phase 1.

Table 103 | Comparison of the Revisions of the Project Master Plan

Category	Master Plan Established (14 Jun. 1990)	1st Revision (14 Jun. 1993)	2nd Revision (31 Jul. 1998)	
			Phase 1	Phase 2
Route	Seoul~Cheonan~ Daejeon~Daegu~ Gyeongju~Busan	Seoul~Cheonan~ Daejeon~Daegu~ Gyeongju~Busan	Seoul~Cheonan~ Daejeon~Daegu~ Busan	Seoul~Choenan~ Daejeon~Daegu~ Gyeongju~Busan
Distance	409km	430.7km	409.8km	412km
Term	1991.8~1998.8	1992.6~2002.5	1992.6~2004.4	2004.5~2010.10
Cost	KRW 5.8462	KRW 10.7400	KRW 12.7377	KRW 5.6981
Stations	Seoul, Cheonan, Daejeon, Daegu, Gyeongju, Busan	Seoul, Gwangmyeong, Cheonan, Daejeon, Daegu, Gyeongju, Busan	Seoul, Gwangmyeong, Cheonan, Daejeon, Daegu, Busan; Seoul Station: Using the existing Seoul Station and the expansion of Yongsan Station	Gwangmyeong, Cheonan, Daejeon, Daegu, Gyeongju, Busan
Travel time	101 min.	124 min.	160 min.	116 min.
Speed	350km/h (max. design speed)	300km/h (max. oper. speed)	300km/h (max. oper. speed)	300km/h (max. oper. speed)
No. of trainsets	46	46	46 (foreign 12; domestic 34)	46
Funding plan	-	Government subsidy 45%; independent funding 55%	Government subsidy 45%; independent funding 55%	-
Major revisions	-	• Renovating and using the existing ground-level Seoul, Daejeon and Daegu Station. • Using the existing Gyeongbu Line between Seoul Sta. and Anyang Sta. • Creating a new station for Gwangmyeong	• Electrifying and using the existing line for the zone that crosses the downtown of Daegu and Daejeon as well as the Daegu-Busan zone. • Using the existing rail between Seoul Sta. and Gwangmyeong Sta.	• Constructing a new railway between Daegu and Busan • Constructing Gyeongju Sta. • Constructing an underground railway that will pass through Daejeon and Daegu

Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

Figure 28 | The Route of Gyeongbu HSR



Source: KRNA, “Gyeongbu HSR Construction History”, 2011

3.1.3. Revision of the Implementation System

1) Implementation Organization

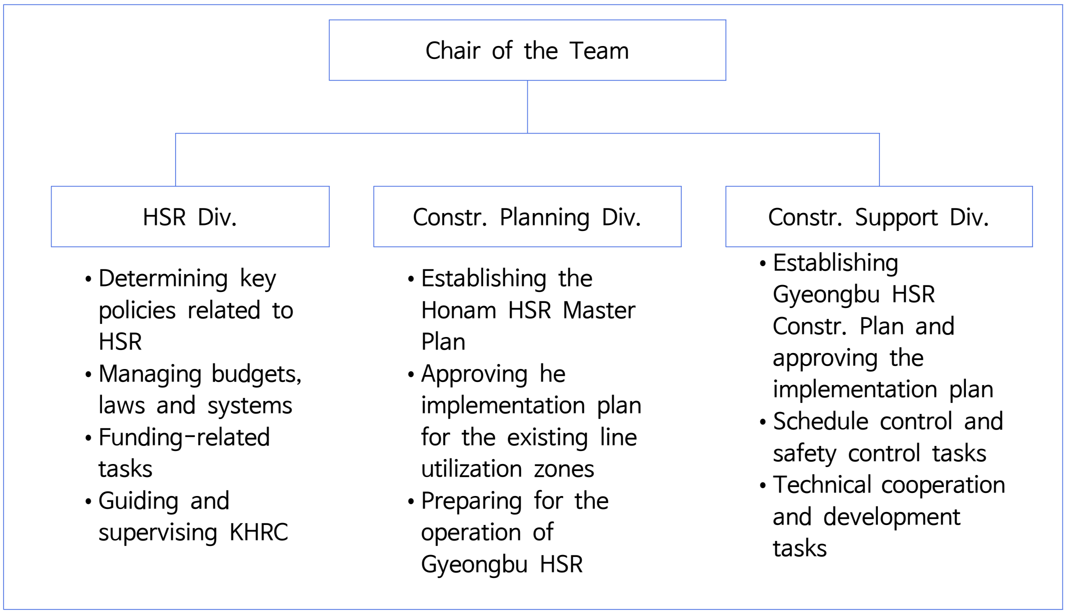
- The most representative implementation organizations for the Gyeongbu HSR Project are the Ministry of Construction and Transportation's (MOCT's) HSR Construction Planning Team, the HSR Construction Headquarters at Korean National Railroad (KNR), Korea High-speed Rail Construction Authority (KHRC), and Social-Overhead-Capital Construction Implementation Committee.
  - The MOCT's HSR Construction Planning Team supervised the establishment, revision, and management of the related laws, the establishment (revision) and announcement of the master plan, determining and planning other key policies associated with the HSR project, approving of the project implementation plan, managing the HSR Construction Review Committee, carrying out other supporting functions for KHRC, and coordinating the tasks between KNR and KHRC.
  - The HSR Construction HQ at Korean National Railroad was commissioned by KHRC to carry out the repairs and electrification of the existing rails and related facilities in the project.
  - KHRC not only undertook the execution of the project but also served as project owner by establishing the implementation plan and supplying funds.
  - The SOC Construction Implementation Committee reviewed and coordinated the key policies (master plan, fund supply, etc.) connected with the construction of the HSR, and oversaw the task cooperation among the departments concerned, organizations and local governments.

a) HSR Construction Planning Team (MOCT)

- History
  - 30 Apr. 1994: The HSR Division (temporary organization) was established (level 4, eight people).
  - 1 May 1996: Reorganized into HSR Promotion Team (nine people id position level 4)
  - 29 Jun. 1996: Reorganized into HSR Department (official organization). (12 people of position level 4)
  - 23 Nov. 1996: The HSR Construction Planning Team was established (22 people of position level 3 in two divisions).
  - 3 Sep. 1997: The Construction Planning Division of the MOCT's HSR Construction Planning Team was expanded (29 people of position level 3 in three divisions).

- Tasks & functions
  - Establishing and adjusting HSR plans and policies
  - Establishing and modifying the investment and funding plans for HSR
  - Guiding and supervising KHRC

Figure 29 | HSR Constr. Planning Team's Organization Chart



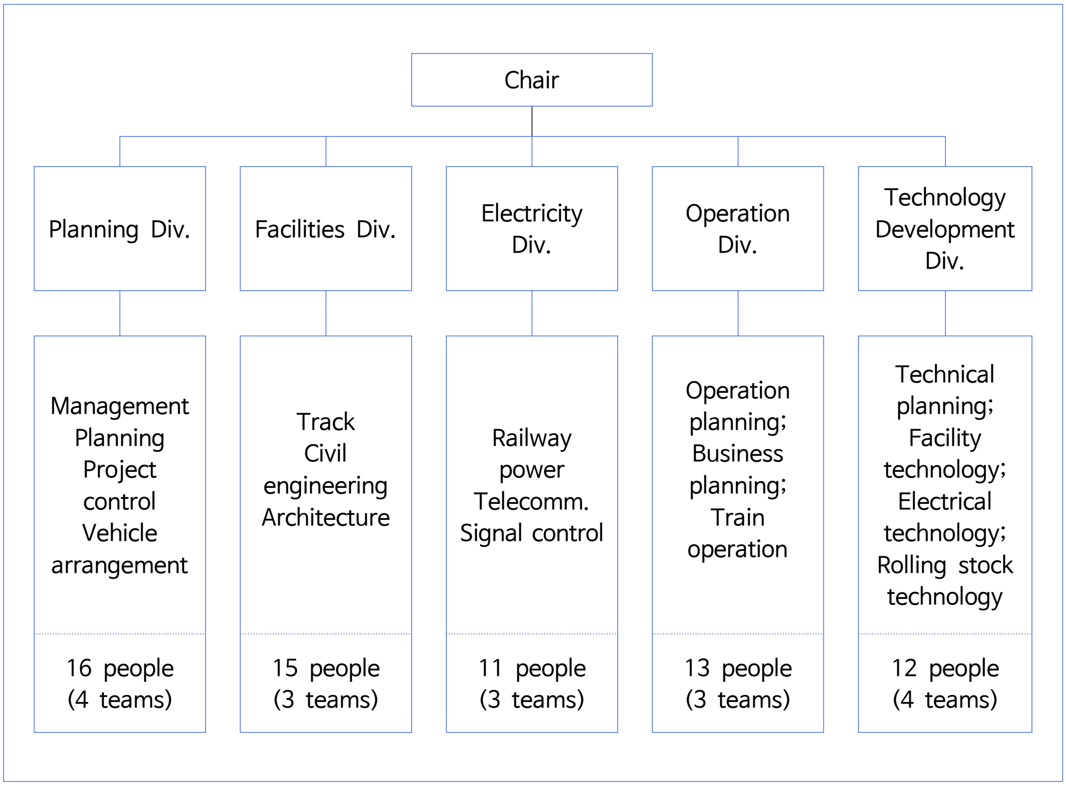
Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

b) HSR Headquarters (Korean National Railroad)

- History
  - December 1989: The HSR Construction Task Force (HSR Planning Team) was established.
  - December 1994: The HSR Operation Preparation Team was set up.
  - July 1996: The Technology Promotion Management Team was transformed into the HSR Management Team.
  - July 1997: The HSR Training Division was established within KNR Officials Training Center.
  - August 1998: The HSR Management Team was renamed HSR Project Management Team; the HSR Organization Management Team was established.
  - July 1999: The HSR Headquarters was established (1 chairmain, 76 people in five divisions, 20 teams).
  - January 2000: The HSR Construction Project Office was founded within the Headquarters (1 chairmain, 118 people in 6 divisions and 22 teams).

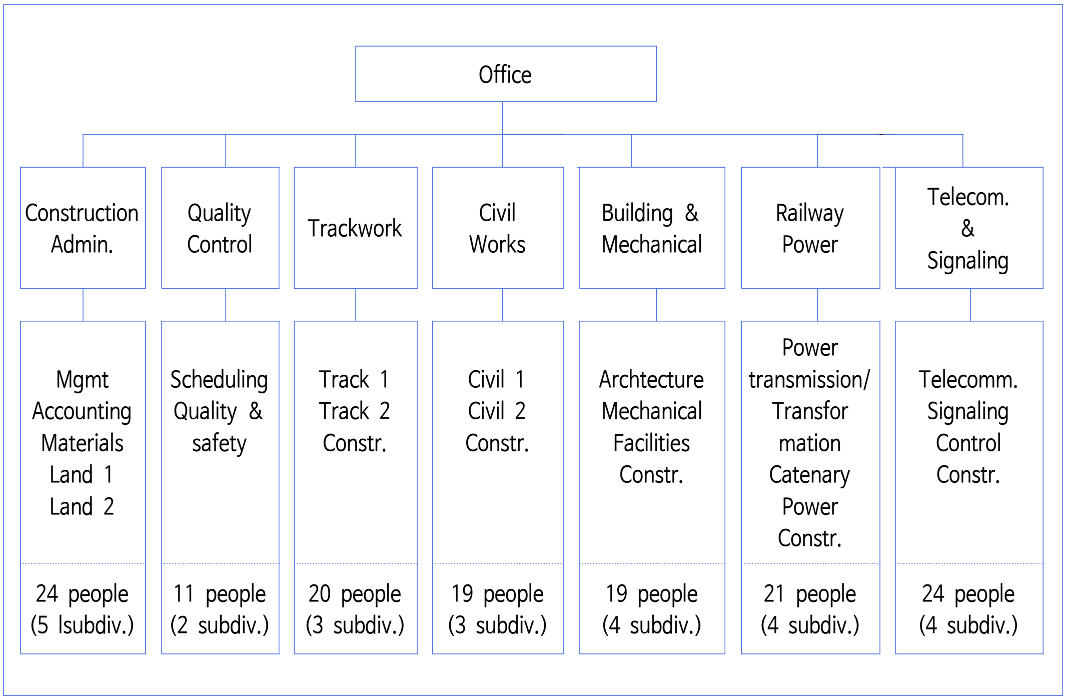
• Tasks & functions
Systematic execution of the budget and schedule control for rail system maintenance and repair works (including the electrification of the existing rails) in the HSR Construction Project
- Formulating design, construction, and maintenance plans in the facilities and electricity disciplines connected with the project
- Preparing for the operation of the HSR
- Systematic promotion of the railway technology development

Figure 30 | HSR Headquarters' Organization Chart



Note: Excluding the regular personnel at the branch offices and the dispatched R/S management team (T/F)
Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

Figure 31 | Organization Chart of the HSR Constr. Office



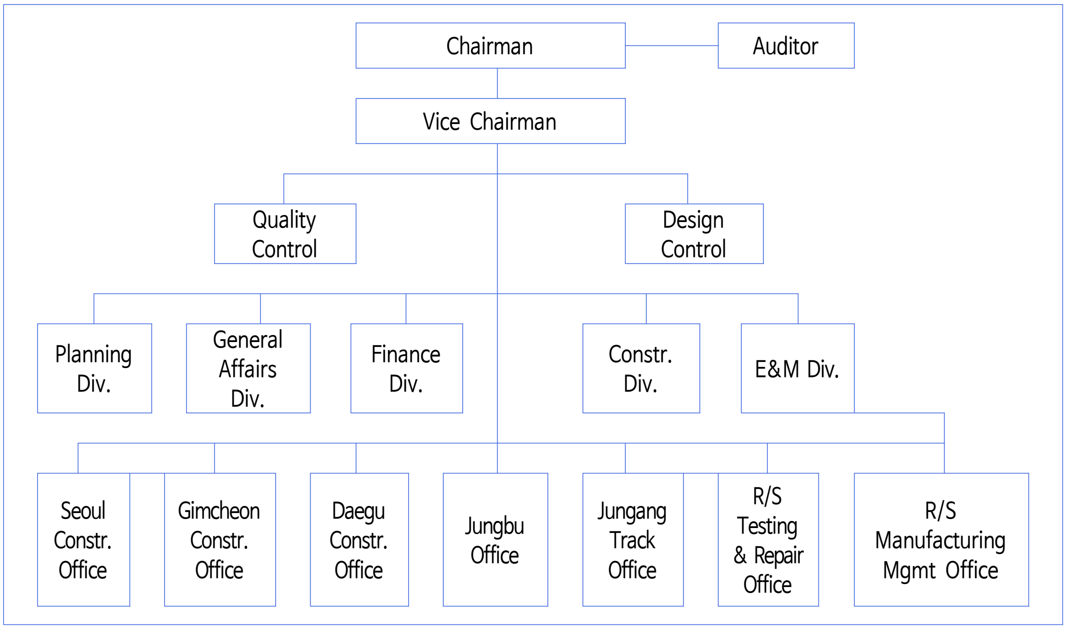
Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

c) Korea High-speed Rail Construction Authority (KHRC)

- History
  - July 1989: The HSR & New International Airport Constr. Implementation Committee & Task Committee were set up.
  - Implementation Committee: 17 members, excluding the Minister of Economic Planning Board (Chair)
  - Task Committee: 22 members, excluding the Vice Minister of Transportation (Chair)
  - December 1989: The Task Force Team was established (54 KORAIL employees).
  - February 1991: The HSR Project Planning Team was established (140 people).
  - December 1991: KHRC Act (Act No. 4456) was enacted.
  - March 1992: KHRC was established (379 people in seven divisions).

- Tasks & functions
  - Constructing the HSR
  - Carrying out HSR station vicinity areas and wayside development projects
  - R&D and survey of HSR technologies

Figure 32 | Organization Chart of KHRC



Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

d) SOC Construction Implementation Committee

- Establishment Grounds
  - Provision on the High-speed Rail and New International Airport Construction Promotion Committee (Presidential Decree No. 12762 enacted on 24 Jul. 1989)
  - Amendment of the Provision on the SOC Infrastructure Promotion Committee (Presidential Decree No. 15173 partially amended on 23 Nov. 1996)

- Tasks & functions
  - Reviewing and adjusting the master plan and key policies on the construction of HSRs, new international airports and new ports
  - Issues related to the establishment of the construction master plan for HSRs, new airports and ports
  - Issues related to interdepartmental cooperation with regard to the construction of high-speed rails, new airports, and harbors

- Organization (30 people including the chairman and vice chairman)
  - Chairman: Minister of Planning & Budgeting
  - Vice chairman: Minister of Construction & Transportation, Minister of Maritime Affairs & Fisheries

- Members: Ministers of Public Administration and Security, National Defense, Agriculture and Forestry, Commerce, Industry and Energy, Information & Communication, Environment, Science & Technology, and Office for Government Policy Coordination; Presidential-Secretariat Economic-Division secretary; Director of Forest Services; Director of Korean National Railroad; Seoul Metropolitan City Mayor; mayors of metropolitan cities; governors; Chairman of KHRC; Chairman of Incheon International Airport; and others related to the issues to be reviewed and appointed by the chairman

• Task Force Committee (30 or less people including the chairman and vice chairman)
- Chairman: Vice Ministers of Construction & Transportation, Maritime Affairs and Fisheries
- Vice chairman: Director of the Conveyance Policies Office at MOCT, Director of Planning and Management at the Ministry of Maritime Affairs and Fisheries
- Members: Ministers of Strategy & Finance, Public Administration and Security, National Defense, Culture & Tourism, Agriculture & Forestry, Commerce, Industry & Energy, Information & Communication, Environment, and Science & Technology; Office of Planning & Budgeting; Office of Government Policy Coordination; Office of Forest Services; KNR; Presidential Secretariat; directors of Seoul City and other cities and provinces concerned; Vice Chairmen of KHRC and Incheon International Airport; and those appointed by the chairman

2) Relevant Laws

a) Provision on the High-Speed Electric Rail & New International Airport Construction Promotion Committee

• The provision on the High-speed Rail and New International Airport Construction Promotion Committee was enacted in 1989 to review and coordinate the master plan and important policies for the construction of the high-speed rail and a new international airport.

• This Act defines the functions and composition of the committee, the composition of its working committee, and other necessary matters regarding its operation (in November 1996, the provision was re-named into “Provision on the SOC Infrastructure Construction Promotion Committee.”).

b) The Korea High-speed Rail Construction Authority (KHRC) Act

• The KHRC Act was enacted in 1991 to establish KHRC to construct the high-speed rail efficiently for the purpose of expanding the rail transport networks, in an effort to enhance public transportation convenience and help stimulate national economic development.

• This Act defines KHRC's business scope, composition/ qualifications of the officers, financing schemes, collection of service fees, and other overall matters associated with the operations of KHRC.

c) The High-speed Rail Construction Promotion Act

• The HSR Construction Promotion Act was enacted in 1966 to set forth matters required for the early construction of the HSR so as to efficiently implement the HSR construction project.

• This Act defines the term of the HSR, the development of the master plan for the HSR construction, implementers of the HSR construction project and supervision of the project, designation of the prearranged areas for the project, and other matters regrarding the construction of the HSR.

Table 104 | Laws Pertaining to the High-speed Rail

Relevant laws	Purpose	Outline	Date of enactment
Provision on the High-speed Electric Rail and New International Airport Construction Impulsion Committee	To deliberate on and coordinate the master plan and important polices for the construction of the high-speed electric rail and new international airport	Defining the committee's function, composition, and working committee composition, and other matters necessary for the operation of the committee	24 July 1989
KHRC Act	To establish the KHRC so as to efficiently construct the high-speed rail for the purpose of expanding Korea's rail networks	Defining the business scope, officer composition and qualifications, financing methods, collection of service fees, and other overall matters necessary for the operation of the Authority	27 December 1991
High-speed Rail Construction Promotion Act	To define matters required for the early construction of the HSR so as to efficiently implement the HSR construction project	Defining the master plan and the implementation plan for the HSR construction, the project implementers, supervision of the project, the Act's correlation with other laws, designation of the prearranged areas for the rail, and other matters regarding the construction of the HSR	31 December 1996

Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

3.1.4. Vehicle Type Selection & Contract Conclusion

- Main tasks of the Gyeongbu HSR Project included the selection of vehicle type and technology transfer. The process of selecting the vehicle type began by sending an RFP to three countries—France, Germany and Japan—on 26 August 1991.

1) Results of the Negotiations

- The following results were obtained through six phases of proposal evaluation and negotiations:

Table 105 | Negotiation Results

Category	Description
Price	• USD 2.1016 billion (an about 43% reduction from the highest price pro
Technology Transfer	• Unprecedented technology transfer and localization of over 50% of the production cost • Securing the right to supervise KHRC in all technology transfer and localization processes
Localization	• If the localization failed to meet the goal, 20% of the rest of the amount will be paid as penalty.
Technology Transfer Fees	• Reduction of the technology transfer fees: Free prepaid technical fees; sales technical fees reduced from 2.5% to 2%
Technological Development Right	• Securing the manufacturer's production, testing, sales, and world market advancement rights (except for the European and North American markets, on which further negotiation is required) • Guaranteeing KHRC's right to use the already-developed technologies and ownership of the new technologies developed during the project
Warranty Period	• Guaranteeing the performance for two years after the acquisition, and a five-year warranty after the contract period for unpredictable defects
Work Participation Rate	• Joint and several responsibilities among consortium-participating companies over all the tasks performed
Other	• Drastic improvement of various other contract conditions, operation experiences, and scheduling

Source: Ministry of Strategy & Finance, "Economic Development Experience Modularization Project: Korea's HSR Construction", 2012

2) Concluding the contract on the introduction of core systems including rolling stock

- On 14 June 1994, KHRC, the project owner, and Korea TGV Consortium, the supplier, signed the core system introduction contract.

Table 106 | Concluding the Contractor on the Introduction of Core Systems Including R/S

Category	Description
Price	• Total contract amount: USD 2.1016 billion (about KRW 1.682 trillion) • Offshore scope: FFr 6.009542 billion • Onshore scope: USD 1.069843 billion
Supply scope	• Design of 46 trainsets (basic, detail and production designs), manufacturing, delivery of the completed rolling stock, testing and preparation for the operation • Design (basic, detail and production designs) of the catenary, manufacturing, materials procurement, supervision of the installation and detail design, testing and preparation for the operation • Technical data, training and technical support for the technology transfer of the French company, the contractor, and the localization of over 50% of the equipment manufacturing price • Training, testing and commissioning, development of O&M guidelines, supply of spare parts and maintenance tools, establishment and execution of maintenance plans (for two years), offering of various services, etc.
Key contract conditions	• Dispute mediation: Based on the mediation regulations of Korea Commercial Arbitration Board, both parties appoint one arbiter each, and a third-party arbiter is appointed by Korea Commercial Arbitration Board. • Project deliverables: KHRC owns the copyrights. • Inspection and testing: KHRC has the right to review, request proof for, attend to, and reject the tasks or delivered goods if these do not comply with the contract provisions. • Right to audit: KHRC has the rights for claims and cost reimbursement, and owns the right to investigate if the target localization has been achieved. • Interface management: The interface management responsibilities shall be shared by the contractor and the concerned companies, and shall include the related tasks. • Intellectual copyrights: Securing KHRC's right to use the already-developed intellectual properties as well as the right to own the intellectual properties developed during the project. • Contractor's liability for reparation: Within 10% of the total contract amount against the direct damages or claims that may arise during the project. • Right to suspend tasks: KHRC reserves the right to suspend some or all of the related tasks.

Source: Ministry of Strategy & Finance, "Economic Development Experience Modularization Project: Korea's HSR Construction", 2012

3) Concluding the Contractor for the Introduction of Public Loans

• On 16 December 1993, KRNA established the Public Loan Introduction Plan 1994 in order to introduce loans in accordance with the financial conditions proposed by France.

Table 107 | Chronology of Formulating the Public Loan Introduction Contract

Date	Description
26 August 1991	• The RFP was sent out to Germany, Japan and France. • The South Korean government would be the loaner and guarantee the payment of part of the whole proposed loan amount. • The loan would be used to cover 100% of the rolling stock and other core system costs and the other domestic costs.
July - August 1993	• Ministry of Finance's opinions on KHRC's foreign- loan plan • The foreign loans, out of the loans for the rolling stock and other core system costs would be obtained as public loans, but a plan was required to minimize the contract charges. • The localization cost was a kind of cash loan, and since after August 1986, foreign loans was restricted under the foreign-investment policy, to obtain foreign-currency domestic loans, it was necessary to provide various plans for the use of the loan.
20 August 1993	• Final finance proposal by Alsthom, France, which was selected as the preferred negotiation partner
10 September 1993	• During the meeting with the Vice Prime Minister and the Ministers of Finance and of Transportation after the meeting with the Minister of Economy, it was determined, as a policy, to proceed with obtaining public loans also to cover the localization costs.
24 September 1993	• Submitted a public-loan application to the Ministry of Finance • Loaner: South Korean government • Project owner: KHRC • Estimated loan amount: USD 2.74 billion • Projected loanees: International loan team, including Indosuez Bank in France
16 December 1993	• The original motion on the introduction of public loans was passed at the National Assembly's 165th general meeting, with the conditions below. • The government would stipulate the early-repayment and cancellation rights on the loan contract, and report every three years to the National Assembly if early repayment and cancellation would be necessary, which the National Assembly might review.
12 August 1994	• The public-loan contract was concluded. • Loaner: Minister of Finance • Loanees: 25 South Korean and foreign financial institutes, including Indosuez Bank (seven South Korean and 18 foreign institutes) • Loan amount: USD 2.337 billion (USD 1.617 billion export finance; USD 722 million tied finance)
26 August 1994	• The public-loan subcontract was sealed between the Ministry of Finance and the Chairman of KHRC, based on Article 26 of the Foreign Investment Act.

Source: Ministry of Strategy & Finance, "Economic Development Experience Modularization Project: Korea's HSR Construction", 2012

Table 108 | Key Loan Conditions Agreed upon by the National Assembly

Category	Export Finance	Tied Loan	Remarks
Amount	USD 1,915 million	USD 825 million	
Interest rate	CIRR	Libor+0.75 (average)	
Term	18 years (including an 8-year deferment)	15 years (including an 8-year deferment)	

Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

Table 109 | Final Loan Conditions

Category	Export Finance	Tied	Remarks
Contract amount	USD 1.67 billion	USD 720 million	
Interest rate	6.25% confirmed based on CIRR	Libor+0.57%	
Terms	10-year redemption by installment (8-year deferment)	7-year redemption by installment (8-year deferment)	
Charges	Management charges: 0.4% Contract charges: 0.28% per year	Management charges: 0.7% Contract charges: 0.3% per year	
Capitalization	Interest and insurance premium	interest	
Usage	Foreign-equipment purchases, export insurance premium, interest and market price increase during the construction	Advance, South Korean equipment purchases, interest during the construction	

Note: Based on the rolling stock contract results on 14 June 1994, the loan amount was reduced from that agreed upon by the National Assembly.
Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

4) Concluding the train radio system supply contract

• All three countries proposed the radio system that was being used in their own country. But this equipment was old and in an analogue format. Thus, the train radio system was separated from the core system and was ordered separately. After the request for project proposals in the newspapers in ten countries, including Germany, the US, and the UK, seven companies from the US, Germany, Switzerland and France showed interest in participating in the project. In May 1994, the deadline for the proposals, Motorola was chosen as the preferred negotiation partner, and after negotiations with the company, the negotiation team signed the contract with it on 22 April 1995 at about USD 83.4 million.

Table 110 | Basic Requirements of the Train Radio System

Description
• Efficient support of the centralized control system for all trains
• Securing the communication zone in over 98% of all the system zones
• Securing sufficient data and voice communication capacities between the wayside and the train
• Securing the reliability through the establishment of a no-barrier system by doubling the principal equipment and parts
• Zero-disturbance system insusceptible to electromagnetic waves caused by high-voltage lines around the railway
• The central command center can perform surveillance and control functions of the wayside and onboard systems.
• Allowing emergency calls, general calls, and group and individual calls, and allowing the setting of calling priorities
• Allowing handover at a high speed (over 300 km/h)

Source: Ministry of Strategy & Finance, "Economic Development Experience Modularization Project: Korea's HSR Construction", 2012

3.1.5. Finance

1) Financing Plan

• The budget finalized in 1998 was KRW 12.7377 trillion, based on the Project Phase 1.

• To secure the budget, the South Korean government and KHRC established funding principles while concluding the first revised plan in 1993.
  - Government subsidy 45%, KHRC fund 55%
  - Government's financial support methods: Contribution and financial loan for KHRC
  - KHRC's funding method: Issuing bonds, foreign loans and private financing

• The budget determined in the second-phase project plan was KRW 7.9454 trillion, and in 2007, considering the actual rail management, the government's financial support and KHRC's self-funding ratios were adjusted to 50% and 50%, respectively.

Table 111 | Funding Plans for Gyeongbu HSR Phases 1 & 2

Unit: KRW 100 million as per the master plan

Category	Total	Government			KHRC			
		Subtotal	Investment	Loan	Subtotal	Foreign loan	Bonds, etc.	Private financing
Total	202,939	93,998	79,025	14,973	108,941	30,750	75,568	2,623
Phase 1	127,377	57,320	44,582	12,738	70,057	30,750	36,684	2,623
Phase 2	75,562	36,678	34,443	2,235	38,884	-	38,884	-

Source: Ministry of Strategy & Finance, 「2011 Economic Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

5) Funding Performance

- The government's financial support was about KRW 620 billion a year between 1992 and 1999, and after 2000, around 40% of the yearly financial support was offered as a financial loan through the Transportation Project Special Accounting.
  - The financial investment was decreased to KRW 370 billion a year while the financial loans rose to about KRW 250 billion a year.
  - As a result, the government's investment was 30% of the total budget while the financial loan was 15%.

- Among the self-procured financing by KHRC, bond issuance took the largest share of the funding plan (29%).
  - KRW 3.8097 trillion was supplied through the obtaining of the public- funding management fund, and KRW 2.9 trillion was procured from the bonding market.

- The foreign loans took up 24% of total project cost and were procured from 25 international lenders including Calyon of France (the former Indosuez) in the form of public loans.
  - Loans were received in the amount of USD 2.364 billion, of which USD 2.11745 billion was procured as a type of sub-loan in the process of introducing the core systems such as rolling stock.

Table 112 | Funding Plans & Outcomes of Gyeongbu HSR Project (Phase 1)

Unit : KRW 1 billion

Category	Total budget	1992~1999	2000	2001	2002	2003	2004
National budget	5,732	2,634	790	833	737	608	394
Investment	4,458	2,634	590	601	457	151	232
Financial loan	1,274	-	200	232	280	457	162
Self-procurement	7,006	2,609	1,001	1,457	1,085	646	607
Total	12,738	5,243	1,791	2,290	1,822	1,253	1,000

Source: Ministry of Strategy & Finance, 「2011 Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

6) Future Repayment Plan & Measures

• Based on the KORAIL structural reform after the start of the HSR services, the construction and operation of the national railway systems were separated, and the repayment of the funding procured has been made under their respective responsibility.
- Rail construction: KHRC (Approx. KRW 6.8 trillion as of 2004)
- Rail operation: KORAIL (Approx. KRW 4.3 trillion as of 2004).

• KHRC, which does not have the income from service fares, is repaying the debts by receiving track usage fees from KORAIL, but because the railway usage income is less than a half of the interest for the debts, KHRC is having difficulties in repaying the interest.
- For railway usage fees, 31% of the HSR service income is applied.

3.1.6.Project Implementation Challenges & Overcoming Measures

1) Key Factors in the Poor Performance of the Project

a) Lack of technical & institutional experiences

• Although the construction of the test track began in 1992, the Gyeongbu HSR Project was about to be completely dismantled due to the poor preliminary investigations and the lack of experience in high-speed rail projects and of technical know-how.

- As the geological and topographical investigations were not conducted well for the project areas, the workers had difficulties in the construction.
- Particularly in 1994, Alsthom of France was decided as the rolling stock supplier; the interface and safety of the rolling stock and the roadbed were verified; and the design was improved. In this process, the construction was being suspended temporarily.
- In other words, even though the design and construction for structures had to be carried out after the rolling stock system was determined, some construction works had been performed prior to the selection of the rolling stock system, causing inefficiency in the work.

• Also, as the nation's sense of safety grew due to the successive collapses of large-scale structures, the construction was suspended, and safety inspections were performed along with the supplementary works, resulting in little progress in the project.
  - After all, WJE, a safety inspection specialist company of the US, performed safety inspections for 92 structures that had been constructed until April 1996, in order to ensure the safety of the HSR. And as this information was disclosed to the public, people began to believe that the Gyeongbu HSR Project had a lot of defects in the workmanship.

• Also, as arrangements were not made well for land acquisition and land compensation for the project sites, the workers were having difficulties in progressing the project.
  - Insufficient talks were conducted with relevant organizations regarding the cultural assets along the project route, and the talks with residents and local governments had not been made regarding the commercial development of station vicinity areas and land compensation.
  - Particularly for the historic sites in Gyeongju, archeological surveys were not performed and the construction was pressed forward, which gave rise to a social issue and made the project behind schedule.

b) Excessive civil complaints & the NIMBY phenomena

• After the HSR construction was commenced in 1992, the residents around the construction sites began to file complaints, and the objection of the local governments almost suspended the construction.
  - Local residents made collective complaints regarding land compensation; transmission lines and substations posed obstacles to the regional development; and local residents made frequent complaints by requesting that the project be moved to other areas by maintaining that the project was causing their land prices to go down.
  - Besides, civil complaints were raised continuously due to station locations, local residents' intention to make the HSR stop in their areas, service opening years, mining of the

route, rolling stock depot relocation, and renaming of stations.

- During the presidential election in 1993, some candidates made a public pledge to terminate the project completely, and in the middle of the turnover of power, some argued that the construction should be handed over to the next government.

- As the mass media questioned the safety and feasibility of the Gyeongbu HSR, people's opposition to the project grew stronger, throwing the project into a crisis.

- Thus, the government made efforts to resolve the controversy by establishing a policy to resolve the causes of the civil complaints, verify the safety by a third party, and re-construct any structures that would be found defective, and because of that, the construction was gradually brought back onto the right track.

c) Route Change

- Since after the South Korean government announced in June 1992 that it selected the route that passed through the downtown of Gyeongju and would build Gyeongju Station in the northern field 5 km south from the downtown, objections to this decision had been expressed by the cultural, religious, and academic circles.
  - The reason was that they believed that it would damage both directly and indirectly not only the cultural relics and sites in Gyeongju but also the landscape of Mt. Namsan in Gyeongju.

- Then in October 1995, the Ministry of Construction and Transportation (MoTC) and KHRC proposed a plan to move the station from the northern field to Ijori (10 km south from downtown), and another plan not to develop the rail station sphere after the joint survey in the same year, to protect the cultural assets and landscape in Gyeongju.

- MOCT, however, and academic and religious professionals opposed the plans mentioned above due to the insufficient measures to protect the area's cultural assets, arguing in favor of the original route as the construction inefficiency and investment cost would damage the century-old capital and would risk damaging the cultural assets in that area. This made the difference between the two parties even greater.

- Thus, MOCT proposed alternatives that included extending the underground zone to 8.4 km (from 3.5 km) as a revision of the Hyeongsan River route, and relocating the station from the downtown of Gyeongju to Ijori, 10 km south from downtown, but failed to reach an agreement on those matters.

- Around the end of April 1996, the Prime Minister's Office led a joint field survey with the MOCT and the Ministry of Culture and Tourism, joined by the staff of both departments and by independent cultural-assets, urban-planning, and transportation reviewers recommended by the opposing party.

- The basic position of the government on the Gyeongju route was to minimize the potential damage to the atmosphere and to the cultural assets that might be buried there, and to pursue the project without any more hinderances, and at the same time, to consider the transportation convenience of the residents in Pohang, Ulsan and Gyeongju in selecting the location of the route and the station.

- Based on the government's principle, the joint survey team wrote a joint report, based on which the Prime Minister led several meetings with the Minister of Economy, Culture and Tourism, and with the Minister of MOCT, leading to an agreement.

- Based on what was agreed upon, the government determined and announced a new route for Gyeongju in January 1997. The modified route was determined considering that it would minimize the damage to the cultural assets in Gyeongju, and would be technically and economically feasibile. Further, it was determined that the station would be located within the administrative zone of Gyeongju City.

d) Change in the bridge type

- The detail design standard of the high-speed rail was developed by South Korean specialists from July 1987 to February 1991, by referring to the public-design data of the HSRs in Japan, Germany and France.

- In June 1991, the design was entrusted to fourteen South Korean specialist companies, which designed the superstructure of the bridges based on PC box.

- Four test track sections began to be constructed in June 1992, but because of the first project revision in June 1993, which was reviewed and agreed to by the SOC (Social Overhead Capital) Construction Implementation Committee based on the socio-economic situation in the country, the bridge structure type was changed from PC box to PC beam as part of the plan to make maximum cost savings (first type change).

- In August 1993, after Alsthom in France was selected as the preferred negotiation partner, the dynamic behavior of the bridges was examined for the inspection of the bridges' safety at high-speed operation.

- Although the results showed that there was no issues in vibration or deflection, it was recommended that the stiffness of the structures in the Rahmen and PC beam bridges be reinforced to reduce the train vibration and to promote the passengers' comfort.

- Accordingly, considering the long-term stability enhancement and maintenance aspects of the structures, the bridge type was returned to the continuous PC box structure from PC beam in August 1995 (second type change).

- As such, the Gyeongbu High-speed Rail Project experienced various technical conflicts due to the minimal experience of the South Korean technical team in designing high-speed rail systems and because the design was commenced before selecting the vehicle type. The bridge type was finally switched to PC box considering long-term stability and the convenience of maintenance.

e) Environmental civil complaints concerning Mt. Cheonseong

- Environmental civil complaints concerning Mt. Cheonseong, which Gyeongbu HSR was to go through, were raised by Monk Jiyul, who made a request that the construction be stopped completely.

- In November 2004, the Busan High Court dismissed the injunction filed by Monk Jiyul on the construction for the following reasons: "The probability of environmental encroachment by the tunnel construction on the high mountains and swamp areas is considerably low, and the tremendous interest of the public cannot be disregarded on account of the environmental-encroachment disadvantage that has considerably low probability."

- Monk Jiyul protested against the court's decision and appealed to the Supreme Court. He also went on a hunger strike in an effort to express his will to oppose it.

- KHRC agreed to the performance of a joint environmental-impact survey upon the request of Monk Jiyul, and the construction was suspended for three months, during the survey period (August to November 2005).
  - The joint survey was performed by a joint survey team comprising fourteen specialists from each party, and the results were submitted to the Supreme Court and the press in 2006.

- As the joint survey of environmental impacts and the Supreme Court determined in 2006 that "there is no basis for the encroachment of environmental interest," the conflict was effectively ended, but the litigation resulted in an increase in the construction cost and schedule delays.

7) Process of Overcoming the Difficulties

a) WJE's safety inspection

- Due to a series of large-scale disasters, a question was raised regarding the safety of the Gyeongbu HSR Project, a large national project. Furthermore, the continuous changes of the bridge designs, and the consequent reconstruction and structural reinforcement, required the structures to be inspected and their safety to be verified by specialist organizations.

- The ourcomes showed 200 sites for field revisions, 190 sites for repairs, 39 sites for partial reconstruction, and 583 sites for no repair.

b) Establishing poor-construction preventive measures

- There were two main reasons for the poor construction and time delays of Gyeongbu HSR Project:
  - First, the incomplete preparation of design documents and specifications; and
  - Second, the lack of understanding in safety and precision due to the lack of experience in high-speed rail construction.

- Also, due to several incidents of the suspension of the construction, the project focused mostly on meeting the project milestone dates, and consequently, the quality of the construction was neglected.

- This brought forth some long-lasting side effects, such as the mass media's hastily written articles that dealt with various problems, and apathetic social atmosphere, the nation's misunderstanding and indifference of safety.

- Through the safety inspection conducted by WJE, the contractors focused on thorough preparations for construction and safety and quality controls such as a review of problems found from continuous inspections, and Safety Control Promotion Plan was established.

c) Design Verification and Supplementation

- To verify the structural safety and ensure their technical interface with the TGV rolling stock, SYSTRA, an affiliate company of SNCF, commenced on the verification of the designs of the roadbed, trackworks and buildings.

- Owing to the design review, the construction project obtained external reliability and ensured the structural safety of the roadbed structures, and by applying shop drawings for typical types of bridge superstructures, it could improve the constructability and reduce the construction cost.

- Furthermore, the South Korean technical team obtained advanced high-speed rail construction know-how and accumulated advanced technologies on related fields as South Korean technologies.

d) Execution of a Complete-responsibility-based Management System

- For safe operation at the top speed of 300 km/h, a lot of qualified technical personnel was required.

- But the lack of experience in such projects, the contractor's lack of quality consciousness, and the low management level in South Korea, in the initial project implementation period, etc., led to poor construction.

- Accordingly, KHRC introduced a contractor-named construction project system and a complete responsibility-based management system[1] into all the construction sections to carry out checkings and inspections.

e) Establishing a HSR Quality Control System

- To ensure the successful construction and high quality of the HSR, the contractor, the supervising team, and KHRC had separate quality control organizations, and to systematically perform independent inspections, tests, and reviews to prevent the occurrence of quality-related issues, they set up a quality control system.

1) Complete responsibility-based management system refers to a system in which a supervision-specialized company checks the compliance with design documents and drawings and other related documents for a civil construction whose total construction cost is more than 5 billion KRW or a construction whose building floor area is more than 10,000 km2 in total. Also, the company acts for the client by providing technical guidance in quality control, construction management and safety control.

- KHRC performed joint supervision with INGEROP or DEC, which had experience in HSR projects and contributed to the ahievement of high quality by improving the South Korean supervision team's supervision expertise.

- Based on the main quality control system, any issues pointed out to the contractor were divided according to their level of seriousness, and ODNs or NCRs were issued so that the contractor might take necessary measures. On the other hand, KHRC (the headquarters, construction laboratories, and the construction offices) regularly performed inspections and tests on the quality of the materials and on the construction condition at the fields, to maintain thorough and strict quality control.

- Even the structures constructed with such systematic quality control system were put to safety inspection by an independent agency, which closely verified the safety conditions of all the structures to prevent poor construction and reconfirm the project quality.

3.1.7.KTX Operation Condition

1) Traffic Volumes

- The daily traffic volume of KTX was about 100,000 passengers in 2008, which continually rose up to about 160,000 in 2015.

- The seat usage rates of KTX were higher on the weekend than on the week days. In the case of Gyeongbu Line, the average usage rate in 2015 was 101.6%, which indicates that there were more passengers onboard than seats.

- In the case of Honam Line, the seat usage rate during the week in 2015 was 71.2%; on the weekend, 87.1%; and the total average was 78.4%.

Table 113 | Yearly Traffic Volumes of KTX

Unit: 1,000 passengers/day

Line	2008	2009	2010	2011	2012	2013	2014	2015
Total	103.9	102.7	120.3	137.7	143.0	150.0	155.9	165.9
Gyeongbu	86.2	85.0	94.5	107.0	108.1	114.9	119.5	114.3
Honam	17.7	17.7	18.8	20.0	18.8	18.5	18.2	23.8
Gyeongjeon			7.0	9.9	11.3	11.2	12.1	12.6
Jeolla				0.8	4.8	5.4	6.1	8.6
Donghae								6.6

Source: MoLIT, 「Rail Statistics」, 2016

Table 114 | Seat Usage Rates of KTX

Unit : %

Line	2012			2013			2014			2015		
	AVR	WD	WE	AVR	WD	WE	AVR	WD	WE	AVR	WD	WE
Total	94.4	89.5	100.1	91.8	87.4	96.8	97.6	92.7	103.2	96.7	90.6	103.7
Gyeongbu	101.2	97.1	105.8	96.5	92.4	101.1	103.0	98.7	108.0	101.6	96.9	107.1
Honam	68.2	61.0	76.9	70.3	64.7	76.8	72.3	65.4	80.6	78.4	71.2	87.1

Notes: AVR: average; WE: weekdays; WE: weekend
Source: MoLIT, 「Rail Statistics」, 2016

8) Fare Levels

- The fares of KTX are 164 KRW/km for a new high-speed passenger line and 112 KRW/km for an existing passenger line.

- For executive cars, the fare is determined by imposing an additional 40% of the applicable fare.

- The fare for KTX between Seoul and Busan (about 400 km) is 59,000 KRW, or about 69.5% of the flight fare.
  - The fare of TGV in France is 69.5% of a flight fare; ICE in Germany 45.8%; and Shinkansen in Japan 53.5%.

Table 115 | Comparison of Train Fares with Other Modes of Transportation (Seoul~Busan, as of 2016)

Route	Flight (Korean Air)	Flight (Air Busan)	KTX	Saemaul	Express Bus (Top grade)	Mugunghwa
Seoul~Busan (about 400km)	86,100 won	69,000 won	59,800 won	42,600 won	34,200 won	28,600 won
	100.0%	80.1%	69.5%	49.5%	39.7%	33.2%

Source: MoLIT, 「 Rail Statistics」, 2016

9) Operating Income

- Over the recent decade surveyed, the operating income of KTX was on a gradual increase, and in 2015, Gyeongbu Line recorded an operating income of KRW 1.7 trillion; Honam Line KRW 165.7 billion.

• This is equal to about 2.4 to 2.8 times of the operating income from conventional rails. Given the line length, the operating income of KTX is very high.

• High-speed rails are planned to be built continually. With the emergence of new high-speed rails such as SRT, which was opened in December 2016, it is expected to increase continuously in the future, too.

Table 116 | Rail Operating Incomes of Gyeongbu & Honam Lines

Unit : KRW Million

Line Year	Gyeongbu Line		Honam Line	
	KTX	Conventional Rails	KTX	Conventional Rails
2006	826,741	670,562	78,033	71,070
2007	937,423	697,301	77,552	69,057
2008	966,304	712,885	79,454	69,567
2009	940,537	645,370	77,760	63,317
2010	1,068,922	675,852	69,392	64,096
2011	1,305,056	671,389	72,957	61,809
2012	1,403,781	699,485	80,841	63,315
2013	1,501,233	694,946	80,282	62,117
2014	1,563,658	725,259	82,435	62,331
2015	1,721,000	714,677	165,758	59,489

Source: MoLIT, 「Rail Statistics」, 2016

3.2. KTX Operation Effects

3.2.1. Reduction of Travel Time

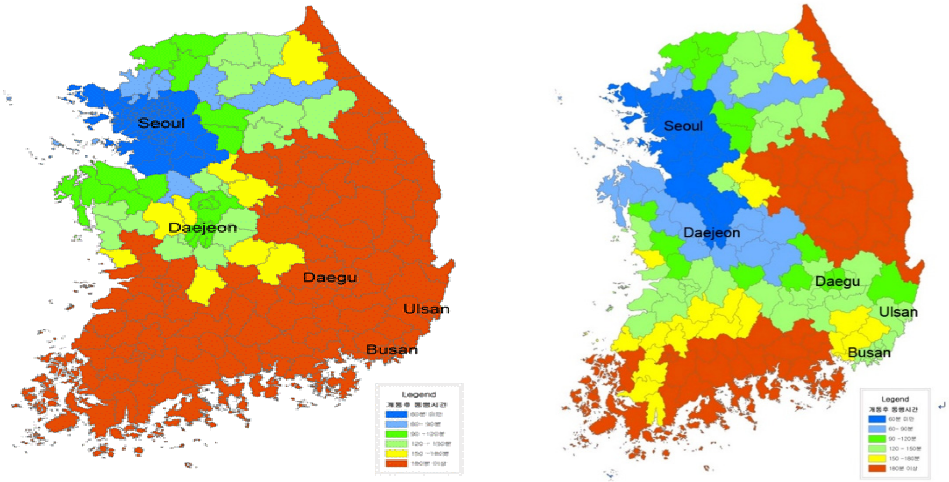
• The introduction of high-speed rails reduced the travel time between Seoul and Busan by half, and thanks to it, any areas along the Seoul-Busan corridor can be reached within half a day.

Table 117 | Comparison of Travel Time before & after the Introduction of KTX

Line	Travel Time		Max. Operating Speed	
	Before (Saemaul)	After (KTX)	Before (Saemaul)	After (KTX)
Gyeongbu Line (Seoul~Busan)	4 hours 45 min.	2 hours 34 min.	140km/h	305km/h
Honam Line (Seoul~Mokpo)	4 hours 34 min.	2 hours 40 min.		

Source: Korea Rail Network Authority (KRNA), 「Gyeongbu HSR Construction History」, 2011

Figure 33 | Comparison of Travel Time before & after HSR Opening along the Seoul-Busan Corridor (departing from Seoul)



〈Before the opening of KTX〉 〈After the opening of KTX〉

Source: Ministry of Strategy & Finance, 「2011 Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

3.2.2. Increase in Rail Travel Demand

- With the opening of high-speed rails, the rail user decreasing trend has been turned into an increasing trend.

- The numbers of Saemaul and Mugunghwa train users decreased in general, but the total number of rail users increased by about 34% for Gyeongbu Line and by about 14.5% for Honam Line.

Table 118 | Rail Usage Trend before & after the Introduction of HSR

Unit : 1,000 passengers/day; %

Line / Train		Before the Opening (2003)	After the Opening (2004)	Variance
Gyeongbu Line (Seoul~Busan)	KTX	0	61	-
	Saemaul	27	22	-18.5
	Mugunghwa	85	68	-20.0
	Total	112	150	33.9
Honam Line (Seoul~Mokpo)	KTX	0	12	-
	Saemaul	4	4	0.0
	Mugunghwa	27	21	-22.2
	Total	31	36	14.5

Source: KOTI, 「Transport System Studies for the Era of HSR」, 2014

- Due to the reduction of travel time, the rail travel demand increased, and the number of rail users increased more on the weekend than on the week days.

- The users growth rate (30%) of Gyeongbu Line on the week days is equal to about twice the rate on the weekend (16%). The number of users of Honam Line increased by 4% on the week days and by 9% on the weekend.

Table 119 | Rail Usage Trend before & after the Introduction of HSR

Unit: 1,000 passengers/day;, %

Line / Train		Before (2003)			After (2004)			Variance		
		WD	WE	AD	WD	WE	AD	WD	WD	AD
Gyeongbu Line (Seoul~Busan)	KTX	-	-	-	52	77	59	-	-	-
	Saemaul	26	34	28	18	25	20	-31	-26	-29
	Mugunghwa	70	124	87	55	82	64	-21	-34	-26
	Total	96	158	115	125	184	143	30	16	24
Honam Line (Seoul~ Mokpo)	KTX	-	-	-	9	19	12	-	-	-
	Saemaul	4	6	4	3	5	4	-25	-17	0
	Mugunghwa	24	38	28	17	24	19	-29	-37	-32
	Total	28	44	32	29	48	35	4	9	9

Note: WD: week days; WE: weekend; and AD: all day.
Source: KOTI, 「Transport System Studies for the Era of HSR」, 2014

• As for the modal split in major sections before the opening of the HSR, the longer the travel distance, the higher the share of rails and flights.

• As for the change of rail travel shares in major sections after the opening of high-speed rails, the rail travel share was much higher in short travel distances than in long travel distances (Seoul-Busan; Seoul-Daegu).

• The rail travel share along the Gyeongbu Line increased by about 23% after the opening (2004), when compared with before the opening (2003).

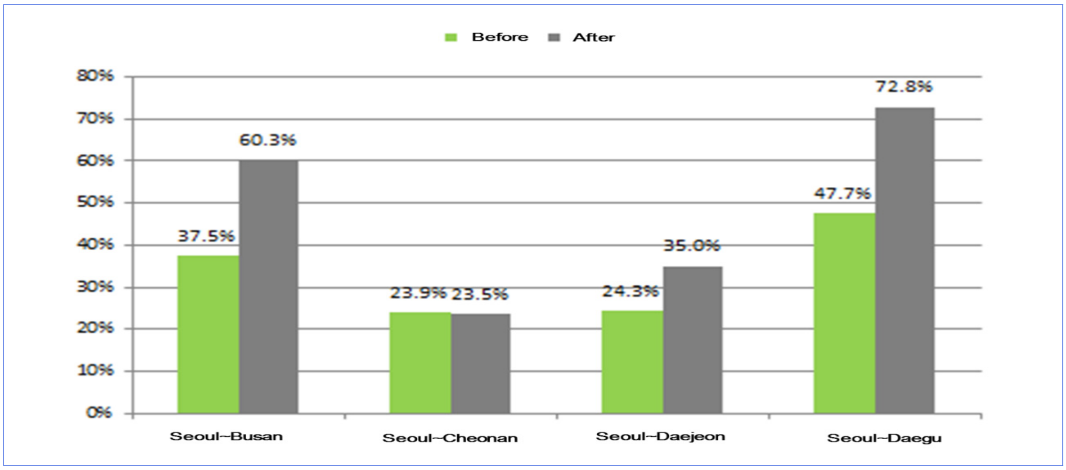
Table 120 | Modal Split Trend before & after the Introduction of HSR

Unit: Persons/day, %

Section / Transport		Before (2003)	After (2004)	Variance
Seoul~Busan	Car	4,656(14.0%)	3,743(9.8%)	-913(-4.2%)
	Express bus	2,267(6.8%)	1,654(4.3%)	-613(-2.5%)
	Flight	13,982(41.7%)	9,792(25.5%)	-4,190(-16.2%)
	Rail	12,502(37.5%)	23,164(60.3%)	10,662(22.8%)
Seoul~Cheonan	Car	33,598(67.9%)	33,296(67..%)	-302(-0.6%)
	Express bus	4,054(8.2%)	4,549(9.2%)	-459(-1.0%)
	Rail	11,834(23.9%)	11,652(23.5%)	-182(-0.4%)
Seoul~Daejeon	Car	25,244(61.9%)	23,059(53.0%)	-2,1858(-8.9%)
	Express bus	5,608(13.8%)	5,228(12.0%)	-380(-1.8%)
	Rail	9,933(24.3%)	15,198(35.0%)	5,265(10.7%)
Seoul~Daegu	Car	4,737(21.9%)	4,049(15.1%)	-688(-6.8%)
	Express bus	2,882(13.3%)	2,194(8.2%)	-688(-5.1%)
	Flight	3,704(17.1%)	1,055(3.9%)	-2,648(-13.2%)
	Rail	10,348(47.7%)	19,518(72.8%)	9,170(25.1%)

Source: KOTI, 「Transport System Studies for the Era of HSR」, 2014

Figure 34 | Rail Transport Share Trends



- In France and Japan as well as in South Korea, the opening of high-speed rails increased the rail travel demand.

- In France, the number of rail users between Paris and Lyon grew 13.5 times from 3,450 people/day before the opening of high-speed rails (1981) to 46,490 people/day after the opening (1987).

Table 121 | Rail User Trends before & after the Introduction of HSR in France

Unit: 1,000 people/day

1981 (before the opening)	1982	1983	1984	1985	1986	1987
3.5	16.7	25.2	37.8	42.1	42.7	46.5

Source: MoLIT, 「Rail Statistics」, 2016

- In Japan, the number of daily rail users increased 10.2 times from 84,000 people before the opening of Shinkansen (1965) to 856,000 people/day after it (2005).

Table 122 | Rail User Trends before & after the Introduction of HSR in Japan

Unit: 1,000 people/day

1965 (before the opening)	1975	1980	1985	1995	2000	2005	2008
8.4	23.2	34.4	49.3	75.4	76.7	82.6	85.6

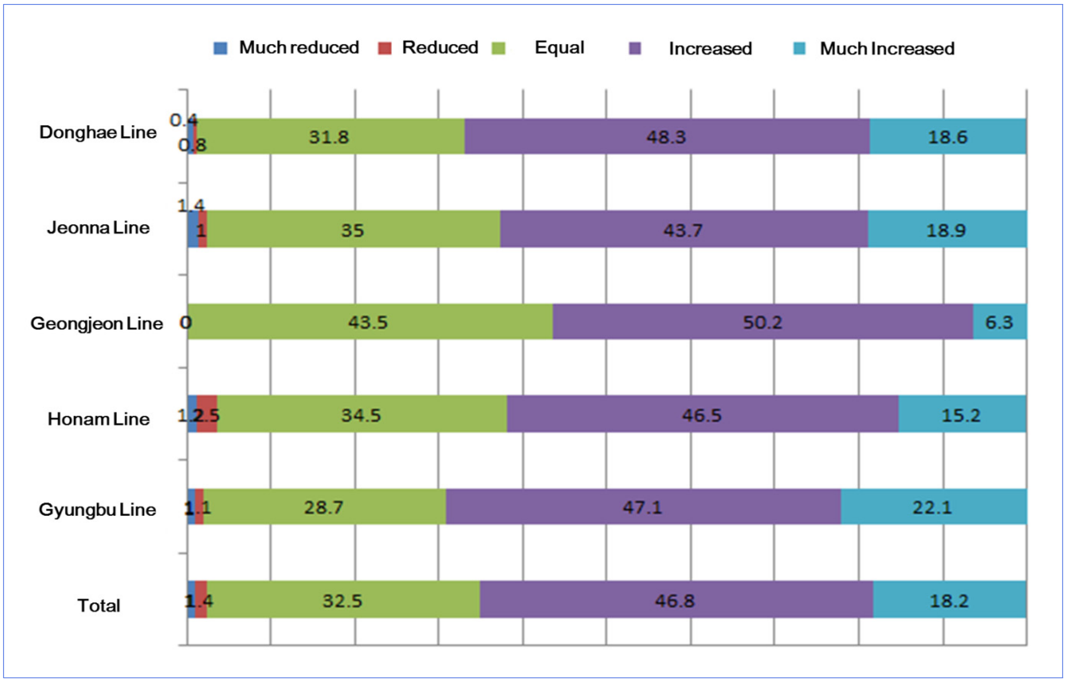
Source: MoLIT, 「Rail Statistics」, 2016

3.2.3. Users' Attitude Change

• With the opening of KTX, KTX users' travel frequencies changed.

- After the opening of KTX, 46.8% of the users said 'a bit increased'; 18.2%'greatly increased. 'This shows that overall travel frequencies increased.
- There were a lot of opinions that after the opening of KTX, travel to other regions became more frequent in general, which had a positive impact on the internal economy and inter-regional economic development.

Figure 35 | People's Attitudes for Travel Frequency Change after the Opening of High-speed Rail Lines



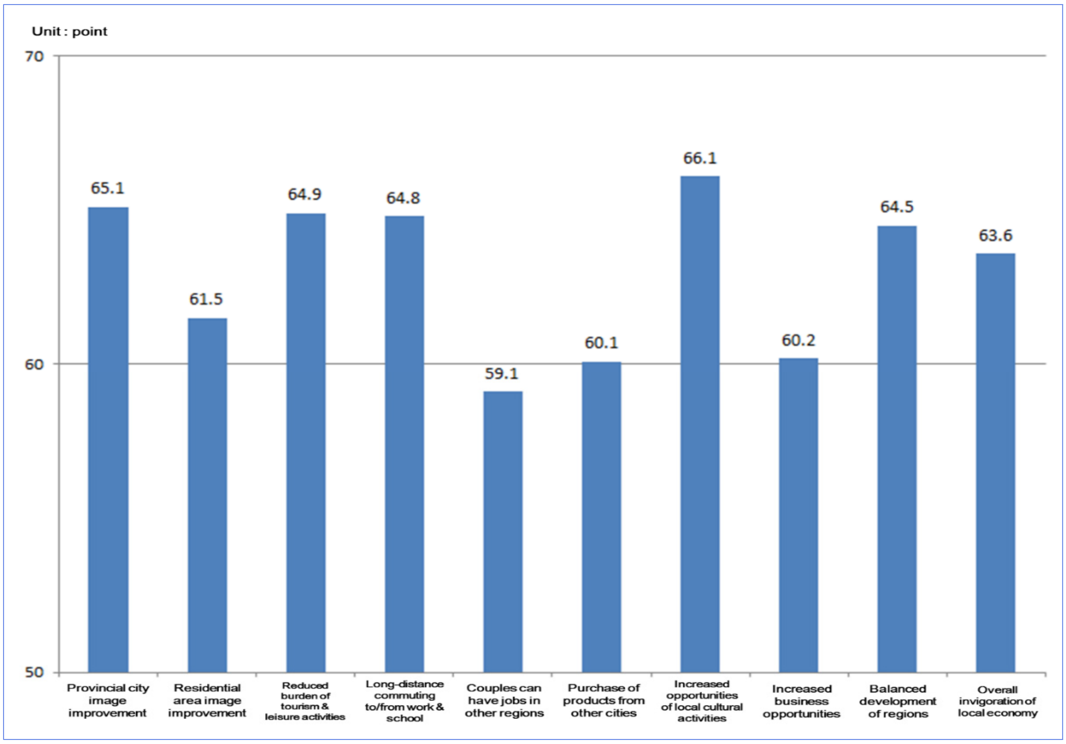
Source: KOTI, 「2015 Support Project for Specialized Development of KTX Economic Zones」, 2015

• After looking into people's attitudes toward the lifestyle change after the opening of KTX lines, we determined that in general, they provided positive assistance for the change of people's lifestyle.

- We converted into scores people's attitude about the lifestyle after the opening of KTX (looking into the attitude in units of 5 points and converting it on the basis of 100 points) and figured out that people had a positive attitude, for 50 or more points were obtained in every item.

• With regard to people's attitude toward the change of their lifestyle, the greatest number of them answered that KTX increased the opportunities of cultural activities in communities, and this reason was followed by the improved image about provincial cities and then by the decrease in their burden about long-distance travel for tourism and leisure activities.

Figure 36 | People's Attitudes toward Their Lifestyle Change after the Opening of KTX



Source: KOTI, 「2015 Support Project for Specialized Development of KTX Economic Zones」, 2015

3.2.4. Socio-economic Effects

• HSR stations are described as Special Economic Zones of KTX and are emerging as the center for commercial activities and transportation in each community, for the capital and technologies rush into them.

• As a result of the reduction of both physical and psychological distances in provincial cities, more and more people are considering those provincial cities when they try to select venues for international meetings, conventions and seminars.

Table 123 | Holding of International Meetings in Cities with KTX Stations

City	2003	2004	2005	2006	2007	2008	Annual Average Growth
Seoul	158	164	155	191	171	193	4%
Busan	19	27	49	82	78	143	50%
Daegu	8	13	11	15	20	16	15%
Daejeon	14	10	7	18	18	53	31%

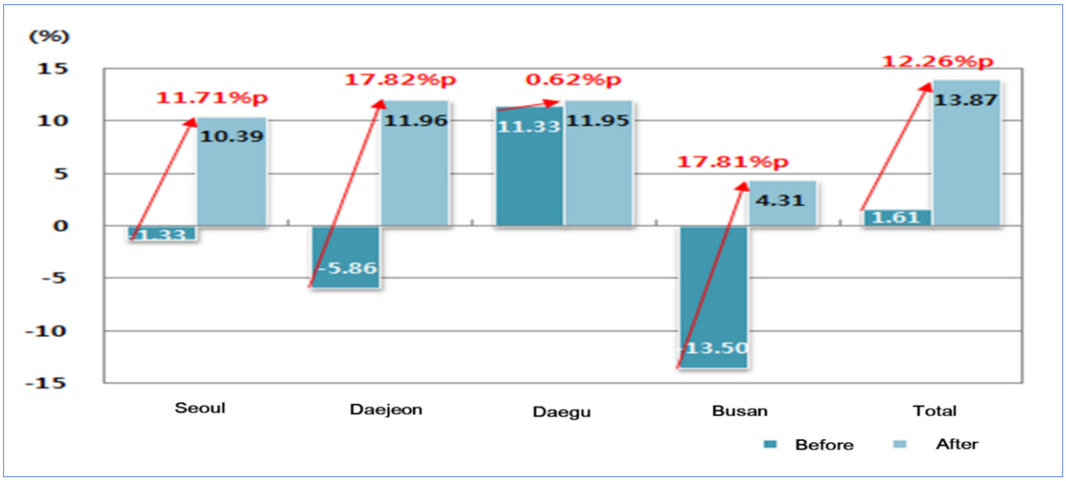
Source: Ministry of Strategy & Finance, 「2011 Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

- After the opening of KTX, the effect on tourism was estimated indirectly by using the sales record on the rooms of tourist accommodations in Busan and Daejeon.

- The analysis shows that the record increased, which means that more and more tourists are visiting the cities.

- Although it may sound unreasonable to explain the effect of increased tourists only as an impact of KTX, it is deemed to have activated local economies owing to the improved image of the city due to the stopping KTX at the city and the reduced travel time and the consequent increase in tourism and leisure demand.

Figure 37 | Tourist Accommodations' Room Sales Growth Trends before & after the Opening of KTX



Note: Before the opening (years 2000~2004); after the opening (2004~2008)
Source: Ministry of Strategy & Finance, 「2011 Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

- Before the opening of KTX, there were concerns that extremely many people would rush into Seoul due to the opening, but such a straw effect was not obvious.

- In the medical field, the opening of KTX is having impact on the travel for using medical services, but rather, the travel demand from Seoul to the cities with KTX stations was higher.

Table 124 | Trend of the Days of Using Hospitals in Other Areas

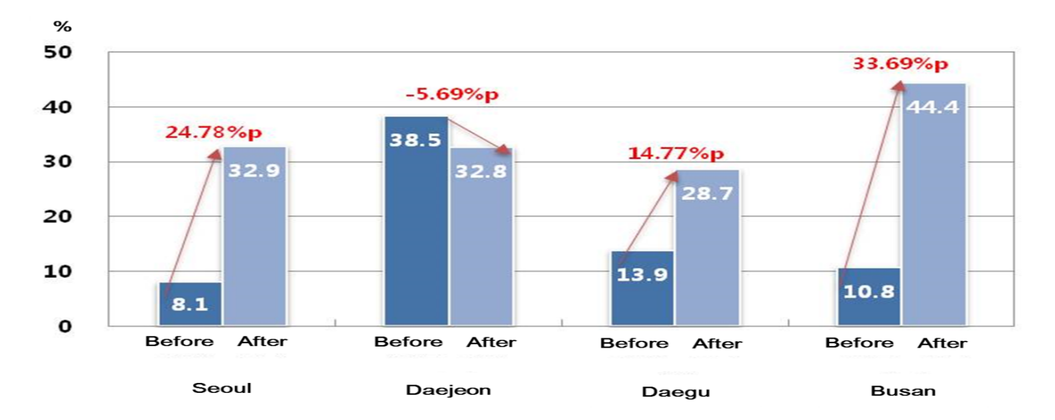
Travel	2003	2004	2005	2006	2007	2008	2009
Seoul→4 cities	895	953	1,037	1,273	2,643	3,556	3,785
4 cities→Seoul	1,236	1,315	1,452	1,656	2,067	2,361	2,536

Note: 4 cities = Daejeon, Daegu, Ulsan, Busan
Source: Ministry of Strategy & Finance, 「2011 Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

- The survey of the growth rates of retail and wholesale turnovers in KTX-stopping cities indicates that it increased by 24.78% in Seoul; 14.77% in Daegu; 33.69% in Busan. And the growth rate decreased a little in Daejeon.

  - People in some provincial cities maintain that the phenomenon of the concentration in the capital region triggered by the opening of KTX became so intense that the provincial cities became less and less competitive.

Figure 38 | Retail & Wholesale Turnover Growth Trend before & after the Opening of KTX



Note: Before the opening (years 2000~2004); after the opening (2004~2008)
Source: Ministry of Strategy & Finance, 「2011 Development Experience Modularization Project: Construction of a HSR of Korea」, 2011

3.2.5. Technological Development due to HSR Operation

- The operation of high-speed rails not only added another product to the existing rail transportation services but also had considerable impact on the advancement of South Korean rail technologies.

- The South Korean government provided continuous support for the localization of high-speed rail technologies, and because of this, a dramatic advancement was achieved in South Korean technologies as shown below.

Table 125 | Technological Advancement due to the HSR Operation

Discipline	Category	Effect
Management system	Reservation & sales system	• 50% automatization (possible to reduce manpower); reservation is interfaced to train operation plan.
Electric signaling	System technology development	• Introduction of work manuals and development of staff's capacities
Rail facilities	Early electrification	• Earlier electrification for an operation directly connected to HSR
Structural maintenance	Technological advancement	• Possible to diagnose various structures precisely due to strengthened safety inspection technologies.
Rolling stock	System improvement	• Preparing various manuals for repairs and maintenance • Developing various parts made in South Korea such as onboard computerized control devices
Other	International recognition	• International academic cooperation with WCRR and others

Source: Korail, 「HSR Performance Studies Commemorating the Fifth Anniversary of Opening the KTX Lines」, 2009

Ⅳ. Yangon~Mandalay HSR Plan

1. HSR Design Criteria

1.1. Track Design Criteria

- For the construction of high-speed rails, various regulations, rules and specifications need to be established for the purposes of consistent design and improved quality.

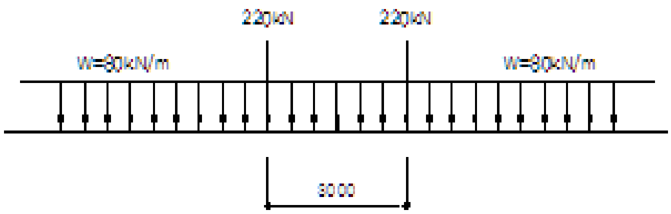
- In this chapter, HSR Construction Regulations are presented on the assumption of the construction of a new high-speed rail, and for the standard concerned, the Railway Construction Rules of South Korea have been applied.

- The Construction Regulations of South Korea and the like had adopted the standards of Japan prior to the construction of high-speed rails, but since then, reasonable standards have been established continuously through an analysis of various European countries' standards and the independent experimental studies of South Korea.

<table>
<tr><th>Item</th><th colspan="3">Standard</th><th>Remarks</th></tr>
<tr><td>Speed</td><td colspan="3">Design speed of a HSR: 350㎞/h</td><td>RCR Article 5</td></tr>
<tr><td>Track gauge</td><td colspan="3">1,435mm</td><td>RCR Article 6</td></tr>
<tr><td rowspan="5">Curve radius</td><td colspan="3">Curve radius of main tracks</td><td rowspan="5">RCR (Rail Construction Rules) Article 7</td></tr>
<tr><td rowspan="2">Design speed V (km/hr)</td><td colspan="2">Min. curve radius (m)</td></tr>
<tr><td>Ballast track</td><td>Concrete slab track</td></tr>
<tr><td>350</td><td>6,100</td><td>5,000</td></tr>
<tr><td>200</td><td>1,900</td><td>1,700</td></tr>
</table>

<table>
<tr><th>Item</th><th>Standard</th><th>Remarks</th></tr>
<tr><td>Curve radius</td><td>(Note) The values other than these are computed by the following formula:
$$R \geq \frac{11.8V^2}{C_{max} + Cd_1 min}$$
Where R : Curve radius (m), V: Design speed(km/h)
C_{max}: Min. set cant (mm)
$Cd_1 min$: Max. cant deficiency (mm)
Before and after stations and in other inevitable cases, the curve radii should be reduced.</td><td>RCR (Rail Construction Rules) Article 7</td></tr>
<tr><td>Transition curve</td><td>Cubic parabola
Of the values computed by the following formulae, it should be the biggest value or above.
$$L_{T1} = C_1 \Delta \qquad L_{T2} = C_2 \Delta C_d$$
Where, L_{T1} : Length of a transition curve for the cant variance (m)
L_{T2} : Length of a transition curve for the variance of cant deficiency (m)
C_1 : A multiple of cant variance = $\frac{7.31V}{1000}$
C_2 : A multiple of the variance of cant deficiency = $\frac{6.18V}{1000}$
ΔC : Cant variance (mm)
ΔC_d : Variance of cant deficiency (mm)</td><td>RCR Article 9</td></tr>
<tr><td>Min. length of tangents and circular curves</td><td>Min. length of tangents and circular curves of main tracks
<table><tr><th>Design speed V(km/hr)</th><th>Min. length of tangents & circular curves (m)</th></tr><tr><td>350</td><td>180</td></tr><tr><td>200</td><td>100</td></tr></table>
(Note) The other values are calculated by the following formula:
$$L = 0.5V$$
Where L : Min. length of tangents & circular curves (m)
V : Design speed (km/h)</td><td>RCR Article 10</td></tr>
</table>

<table>
<tr><th>Item</th><th>Standard</th><th>Remarks</th></tr>
<tr><td>Cant</td><td>
Formula
$$C = 11.8\frac{V^2}{R} - C_d$$
C : Set cant (mm)
V : Design speed (km/hr)
R : Curve radius (m)
C_d : Cant deficiency (mm)
<table>
<tr><td rowspan="2">Design speed V (km/hr)</td><td colspan="2">Ballast track</td><td colspan="2">Concrete slab track</td></tr>
<tr><td>Max. set cant (mm)</td><td>Max. cant deficiency (mm)</td><td>Max. set cant (mm)</td><td>Max. cant deficiency (mm)</td></tr>
<tr><td>200 〈V ≤350</td><td>160</td><td>80</td><td>180</td><td>110</td></tr>
<tr><td>V ≤ 200</td><td>160</td><td>100</td><td>180</td><td>110</td></tr>
</table>
Excess cant shall not exceed 110 mm.
</td><td>RCR Article 8</td></tr>
<tr><td>Track gradient</td><td>
Gradient of main tracks
<table>
<tr><td>Design speed (km/hr)</td><td>Max. gradient (per mil)</td></tr>
<tr><td>200〈 V ≤350</td><td>25</td></tr>
<tr><td>150 〈 V ≤200</td><td>10</td></tr>
<tr><td>120 〈 V ≤150</td><td>12.5</td></tr>
<tr><td>70 〈 V ≤120</td><td>15</td></tr>
<tr><td>V ≤ 70</td><td>25</td></tr>
</table>
Where inevitable such as before and after a station, the gradient can be increased.
</td><td>RCR Article 11</td></tr>
<tr><td>Vertical curve</td><td>
Min. radius of vertical curves for main tracks
<table>
<tr><td>Design speed V (km/hr)</td><td>Min. radius of vertical curve (m)</td></tr>
<tr><td>265 ≤ V</td><td>25,000</td></tr>
<tr><td>200</td><td>14,000</td></tr>
</table>
(Note) The other values are calculated by the following formula: $R_v = 0.35\,V^2$
Where R_v : Min. radius of vertical curve (m),
V : Design speed (km/h)
Where inevitable, it may be reduced to $R_v = 0.25\,V^2$
</td><td>RCR Article 12</td></tr>
<tr><td>Slack</td><td>
Where to be provided: Curves with a radius of 600m or under
Calculation formula
S = 2,400/R-S'
Where, S = Slack (mm), R = Curve radius (m),
S' = Adjusted value (0~15mm)
</td><td>RCR Article 13</td></tr>
</table>

<table>
<tr><th>Item</th><th>Standard</th><th>Remarks</th></tr>
<tr><td>Structure gauge</td><td>Height: 6,450mm
Width: 4,200mm
The structure gauge for curves to be expanded</td><td>RCR Article 14 Securing the clearance
• Crossing a conventional rail: H=7.01m or above
(based on R.L.)</td></tr>
<tr><td>Formation width</td><td>Tangent sections
<table>
<tr><th>Design speed V (km/hr)</th><th colspan="2">Min. formation width (m)</th></tr>
<tr><td rowspan="2">200 〈 V ≤ 350</td><td>Ballast track</td><td>4.5</td></tr>
<tr><td>Concrete slab track</td><td>4.25</td></tr>
<tr><td>120 〈 V ≤ 200</td><td colspan="2">4.0</td></tr>
<tr><td>70〈 V ≤ 120</td><td colspan="2">3.5</td></tr>
<tr><td>V ≤ 70</td><td colspan="2">3.0</td></tr>
</table>
Curve sections: To be expanded as much as the impact by cant</td><td>RCR Article 16</td></tr>
<tr><td>Track center distance</td><td>Main tracks: 4.8m or above
Inside the station: 4.3m or above
R/S depot & maintenance depot: 4.3m or above</td><td>RCR Article 15</td></tr>
<tr><td>Typical train load</td><td>
</td><td>RCR Article 17</td></tr>
<tr><td>Platforms</td><td>Distance from track center to station platform: 1.675m
Platform width: Considering transport demand and necessary facilities
Platform height: 50cm</td><td>RCR Articles 23 and 24</td></tr>
<tr><td>Track protection</td><td>Installing fences against human and animal access
Installing protecting and decting systems against falling objects (For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
<tr><td>Main track crossing</td><td>Prohibition of level crossings (Level crossings are allowed under security systems in the station)
(For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
</table>

<table>
<tr><th>Item</th><th>Standard</th><th>Remarks</th></tr>
<tr><td>Access road & roads parallel with tracks</td><td>When building roads in parallel with tracks, they are connected with general roads and public roads.
To be constructed considering tarck maintenance and rescue in emergency
For places with concern about damages by snow ice, the protection facilities should be provided.</td><td></td></tr>
<tr><td>Protection of lower parts of bridges</td><td>Protection facilities should be provided against collision with cars, driftwoods, ships (For detailed implementation guidelines, refer to the detailed standards.).</td><td></td></tr>
<tr><td>Emergency access road</td><td>This should be constructed at abutments, piers, tunnel portals and major parts that need repairs of tracks.
(For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
<tr><td>Shade installation</td><td>Shades should be provided between the track and its adjacent road. (For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
<tr><td>Vehicle Prevention</td><td>At places with the concern of Vehicle, proper security systems should be provided. (For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
<tr><td>Ventilation & drainage facilities</td><td>Ventilation and drainage facilities should be provided for the underground tracks. (For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
<tr><td>Facilities against flooding</td><td>If necessary, anti-flooding facilities should be provided for the structures for underground tracks. (For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
<tr><td>Space under the bridge</td><td><table>
<tr><th>Planned flood discharge (m3/sec)</th><th>Space under the bridge (m)</th></tr>
<tr><td>〈 200</td><td>0.6</td></tr>
<tr><td>200~500</td><td>0.8</td></tr>
<tr><td>500~2,000</td><td>1.0</td></tr>
<tr><td>2,000~5,000</td><td>1.2</td></tr>
<tr><td>5,000~10,000</td><td>1.5</td></tr>
<tr><td>〉 10,000</td><td>2.0</td></tr>
</table></td><td></td></tr>
<tr><td>Facilities against noise</td><td>Sound barriers and facilities designed to alleviate the noise generated during train operation For detailed implementation guidelines, refer to the detailed standards.)</td><td></td></tr>
</table>

Source: KNRA, ‘Honam HSR Design Guideline (Roadbed)’, 2007

1.2 Station Planning Standard

1.1.1. Overview

- As stations are where passengers get on and get off the trains and make transfers, convenience of use and comfort should be ensured for them.

- Stations should be designed considering train operation plans and the ridership handling capacities.

- The length of platforms is dictated by the maximum consist length of trains and should be determined considering the facility plans for the lines before and after them.

- Transfer stations should be designed allowing for the transfer facilities.

- The track layout in stations should be suitable to high-speed rail operation (HSR-only stations (intermediate passing-through stations), intermediate strategic stations, and the SP (start point) and EP (end point) stations).

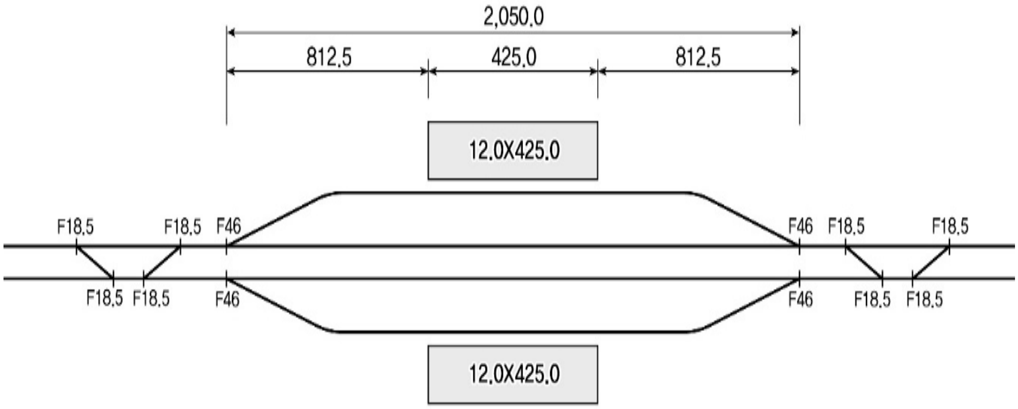
1.1.2. Track Layout Type

- The platforms of high-speed rail stations should be designed so as to be suitable to the handling of high-speed trains.

- The platforms should be arranged considering the departure and destination, turn-back, and passing-through of and transfer to/from high-speed trains.

- The HSR platforms should not be laid out in such a way that the tracks on which high-speed trains pass are arranged next to the platforms and the passing tracks should be arranged so as to be as distant as possible from the platforms.

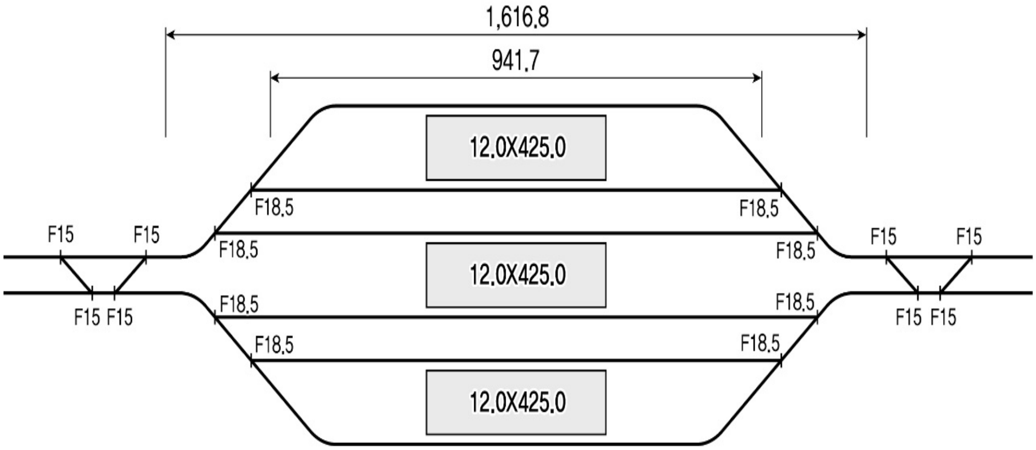
• Layout of 2 platforms and 4 tracks: Intermediate passing-through stations



An intermediate passing-through station with 2 platforms & 4 tracks for the HSR

Source: KOTI, 'Master Plan for Addition of Interim Stations for Gyeongbu HSR,' 2004

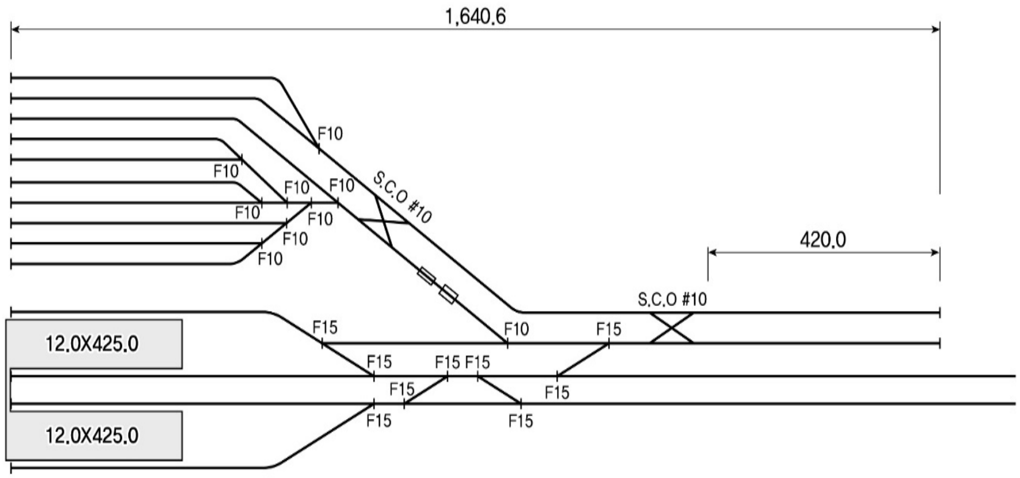
• Layout of 3 platforms and 6 tracks: SP / EP and intermediate foothold stations



SP/EP stations, intermediate foothold stations, 2 platforms and 4 tracks

Source: KRNA, Capital Region HSR (Suseo~Pyeongtaek) Construction Master Plan, 2009

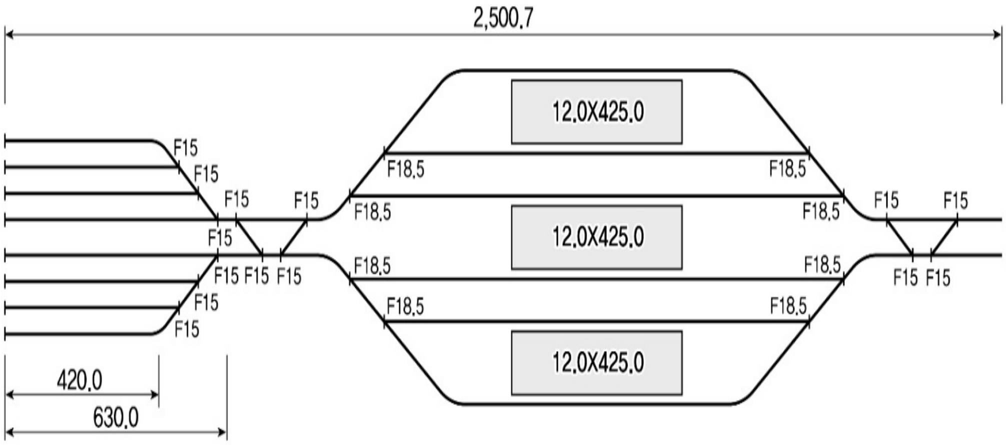
• 2 platforms 4 tracks, storage and turnback tracks on the side of platforms: SP / EP stations of medium and small scale



a medium-sized or small SP/EP station, 2 platforms and 4 tracks

Source: KRNA, Capital Region HSR (Suseo~Pyeongtaek) Construction Master Plan, 2009

• 3 platforms 6 tracks, storage and turnback tracks at the rear of platforms: SP/EP stations of large scale



A SP / EP station, 3 platforms and 6 tracks

Source: KRNA, Capital Region HSR (Suseo~Pyeongtaek) Construction Master Plan, 2009

1.1.3. Braking distance associated with turnout-passing speeds

• The braking distances associated with the turnout-passing speeds on a level straight line not considering gradients and curves are as follows:

Table 126 | Braking Distance Associated with Turnout-passing Speeds

Turnout No.	Curve Radius (m)	Passing Speed (km/h)	s1 (Braking Distance)	s2 (Idle Running Distance)	S (Total Braking Distance)
46#	3,500	170	1084.8	141.7	1226.5
26#	2,500	130	634.4	108.3	742.7
18.5#	1,200	100	375.4	83.3	458.7

Note: These braking distances were calculated based on the braking distances on a level ground without gradients and curves.
Total braking distances are the distances from the end of the turnout to the end of the platform where the train stops.
Source: Master Plan Report on the HSR in Capital Region

2. Review of Station Locations

2.1. Concept of Station Plans

2.1.1. Basic Concept

• High-speed rail stations have the functions of vital organs, integrated traffic centers and civic facilities in cities as well as simple contact points with public transportation systems in major cities. Also, they contribute to the development of communities, respond to the functional changes of rails, and serve as venues for information exchange.

• Particularly, in the construction of high-speed rails, station locations are to be determined with top priority and become bases for the planning of a HSR including route selection.

2.1.2. Considerations for the Selection of Station Locations

- The selection of station locations is based on the transport demand forecast considering population, existing traffic condition (roads, rails, etc.), various plans established, etc.

- Proper inter-station distances that enable the maintenance of the function of a HSR should be secured, and an excessive construction of stations results in lower operating speeds, higher project cost and other adverse elements in rail investment.
  - The average inter-station distance of major countries is 78.5 km. In the case of South Korea, it is only 46 km, but it has secured inter-station distances through an efficient train operation plan. (Depending on the demand, passing or stop is adjusted on a case-by-case basis.

Table 127 | Inter-station Distances for Major Countries' HSRs

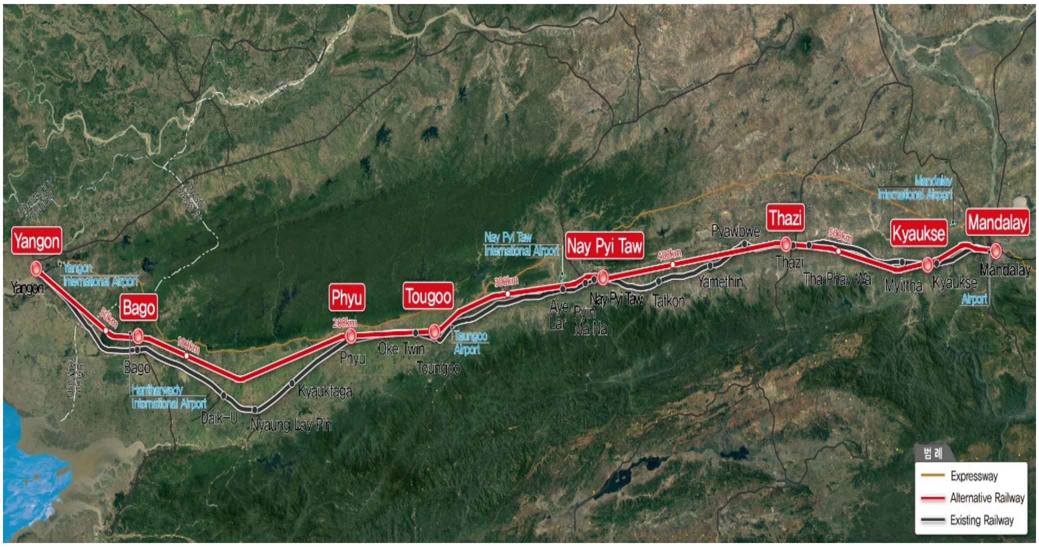
Country		Line Length (km)	No. of Stations	Average Inter-station Distance (km)
Major Countries	France	1,597	21	107.5
	Germany	857	17	78.9
	Italy	954	14	73.4
	Spain	1,931	23	96.9
	Japan	2,568	91	43.1
	US	734	11	73.4
	China	1,068	15	76.3
	Average			78.5
South Korea	Gyeongbu	417.5	10	46.4
	Honam	182.3	5	45.6
	Average			46.0

- When selecting the station locations, the followings should be taken into account:
  - Establishing an efficient interface system with buses, rails, cars, and airplanes
  - Traffic of the country and communities and development plans for new cities and industrial complexes
  - Combined station plans connected with appurtenant businesses such as hotels, shopping and local tourism
  - Avoiding Buddhist cultural assets and historic site preservation areas, military bases, environment reserves and flooded areas.
  - Appropriateness of construction costs: Geotechnical conditions, station types

2.2. Selection of Yangon~Mandalay Station Locations

- The Yangon~Mandalay HSR route passes through Yangon, Bago, Nayphitaw, Mandalay States/Divisions. The population distribution by State/Division, District, and Township is as shown in Tables IV-7, IV-8, and IV-9.

Figure 39 | Yangon~Mandalay Station location map



Source: Google Image

- The existing Yangon~Mandalay railway is about 620 km with 100 stations. Of them, the number of stations with a daily passenger demand of 300 or above is 15. The transport demand by station and the train operation condition are as shown in Tables IV-4, IV-5, and IV-6.

• In this concept, eight stations have been designed considering the transport demand of existing rails, regional populations and inter-station distances (Yangon, Bago, Phyu, Toungoo, Nayphitaw, Thazi, Kyaukse, Mandalay).

• The average inter-station distance of the stations is 82.5 km, which is similar to major countries'average inter-station distance of about 76 km.

• The locations of HSR stations have been selected by referring to the existing rail transport demand and current populations.

Table 128 | Transport Demand of the Existing Yangon~Mandalay Rail

<table>
<tr><th rowspan="2">Station</th><th colspan="2">Distance (km)</th><th rowspan="2">Existing rail demand/day</th><th colspan="4">Population</th></tr>
<tr><th>Location</th><th>ISD</th><th colspan="2">State/Division</th><th colspan="2">Township</th></tr>
<tr><td>Yangon</td><td>0</td><td>-</td><td>2,535</td><td>Yangon</td><td>7,355,075</td><td>Yangon (City)</td><td>7,355,075</td></tr>
<tr><td>Bago</td><td>68.0</td><td>68.0</td><td>1,054</td><td rowspan="3">Bago</td><td rowspan="3">4,863,455</td><td>Bago</td><td>491,130</td></tr>
<tr><td>Pyu</td><td>203.5</td><td>135.5</td><td>439</td><td>Pyu</td><td>256,435</td></tr>
<tr><td>Taungoo</td><td>253.5</td><td>50.0</td><td>936</td><td>Taungoo</td><td>261,737</td></tr>
<tr><td>Nay Pyi Taw</td><td>359.5</td><td>106.0</td><td>1,206</td><td>Nay Pyi Taw</td><td>1,158,367</td><td>Pobba thiri</td><td>116,363</td></tr>
<tr><td>Thazi</td><td>472.0</td><td>112.5</td><td>740</td><td rowspan="3">Mandalay</td><td rowspan="3">6,145,588</td><td>Thazi</td><td>202,497</td></tr>
<tr><td>Kyaukse</td><td>557.0</td><td>85.0</td><td>309</td><td>Kyaukse</td><td>257,545</td></tr>
<tr><td>Mandalay</td><td>596.0</td><td>39.0</td><td>2,346</td><td>Mandalay (District)</td><td>1,725,949</td></tr>
</table>

• As the distance between Bago and Taungoo is the longest, it is deemed appropriate to locate a station in Nyaunglebin rather than in Pyu, but because Pyu is more populous, we have suggested to situate the station in Pyu.

Table 129 | Yangon~Mandalay Travel Demand by Existing Passenger Trains & Train Operation Condition

Station	Number of Passengers of express train per day in FY2012	Express					Mail	
		11UP/ 12DN	5UP/ 6DN Night	3UP/ 4DN Night	31UP/ 32DN	7UP/ 8DN Night	1UP/ 2DN Night	9UP/ 10DN
Mandalay	2,346	○	○	○			○	
Myitnge	141						○	
Kyaukse	309		○	○			○	
Minzu	23						○	
Myitthar	172	○		○			○	
Kume Road	59						○	
Thapyedaung	161						○	
Thedaw	338	○		○			○	
Hanza	27						○	
Thazi	740	○	○	○			○	
Nyaungyan	126	○					○	
Pyawbwe	704	○		○			○	
Shweda	-						○	
Yamethin	326	○		○			○	
Tatkon	702	○	○	○			○	
Kyidaunggan	256						○	
Nay Pyi Taw	1,206	○	○	○	○	○	○	
Pyinmana	454		○		○		○	○
Ela	110						○	
Thawati	-						○	
Yeni	142			○	○	○	○	
Myohla	35				○		○	
Swa	103			○	○		○	
Yedashe	114		○	○			○	
Taungoo	936	○	○	○	○	○	○	○
Oktwin	2						○	
Zeyawadi	-						○	
Pyu	439	○		○			○	○
Kanyutkwin	205	○			○	○	○	○
Penewgon	230			○	○	○	○	○
Kyauktaga	230	○					○	○
Painzalok	-						○	○
Nyaunglebin	463	○		○	○		○	○
Pyuntaza	117			○			○	○
Daik-U	481	○		○	○	○	○	○
Paungdawthi	93							○
Pyinbongyi	0							○
Bago	1,054	○	○	○	○		○	○
Kyauktan	44							○
Togyaunggale	220	○		○	○	○	○	
Stopping Station	18	10	21	13	8	38	15	
Running Time between the starting station to the terminal	16:30	15:30	16:15	10:00	9:30	23:00	11:20	
Commercial Speed(km/h)	37.6	40.0	38.2	37.3	39.3	30.0	31.9	

Source: Feasibility Study on the Rehabilitation and Modernization of Yangon~Mandalay Railway (JICA, 2014)

Table 130 | Populations of the States/Regions along the Project Route

State/Region	Total	Urban	Rural
Union	50,213,067	14,864,119	35,348,948
Kachin	1,643,054	590,462	1,052,592
Kayah	286,738	72,444	214,294
Kayin	1,502,904	329,127	1,173,777
Chin	478,690	99,905	378,785
Sagaing	5,320,299	909,478	4,410,821
Tanintharyi	1,406,434	337,513	1,068,921
Bago	4,863,455	1,070,346	3,793,109
Magway	3,912,711	591,396	3,321,315
Mandalay	6,145,588	2,137,025	4,008,563
Mon	2,050,282	570,432	1,479,850
Rakhine	2,098,963	354,941	1,744,022
Yangon	7,355,075	5,156,646	2,198,429
Shan	5,815,384	1,394,691	4,420,693
Ayeyawady	6,175,123	873,046	5,302,077
Nay Pyi Taw	1,158,367	376,667	781,700

Table 131 | Populations of the Districts/Townships along the Project Route

YANGON	7,355,075		
NORTH YANGON	2,605,021	SOUTH YANGON	1,416,154
Insein	305,670	Thanlyin	267,946
Mingaladon	332,520	Kyauktan	132,354
Hmawby	244,279	Thongwa	157,774
Hlegu	269,522	Khayan	157,564
Taikkyi	277,165	Twantay	226,803
Htantabin	145,768	Kawhmu	118,775
Shwepyitha	343,270	Kungyangon	111,485
Hlinethaya	686,827	Dala	173,376
		Seikkyi/Khana	33,978
EAST YANGON	2,364,536	Cocogyun	1,430
Thingangyun	209,301	Tada(ST)	34,669
Yankin	70,992	WEST YANGON	969,364
South Okkalapa	160,956	Kyauktada	29,796
North Okkalapa	332,869	Pabedan	33,264
Thakayta	220,447	Lanmadaw	47,123
Dawbon	74,994	Latha	24,926
Tamway	165,348	Ahlon	55,412
Pazuntaung	48,245	Kyimyindine	111,566
Botahtaung	40,849	Sangyoung	99,772
Dagon South	371,579	Hline	160,018
Dagon North	203,883	Kamayut	84,368
Dagon East	165,518	Mayangon	198,038
Dagon Seikkan	167,346	Dagon	25,563
Mingala Taungnyunt	132,209	Bahan	96,703
		Seikkan	2,815

Table 132 | Populations of the Districts/Townships along the Project Route

BAGO	4,863,455	MANDALAY	6,145,588
BAGO	1,768,335	MANDALAY	1,725,949
Bago	491,130	Aungmyetharzan	266,365
Tanatpin	145,001	Chanayeharzan	197,312
Kawa	196,746	Mahaaungmye	240,756
Waw	176,024	Chanmyatharzi	283,305
Nyaunglebin	199,709	Pyigyidagun	237,395
Kyauktaga	250,948	Amarapura	236,748
Daik U	201,526	Patheingyi	264,068
Shwegyin	107,251		
		PYIN OO LWIN	996,438
TOUNGOO	1,122,679	Pyin Oo Lwin	251,385
Toungoo	261,737	Madaya	257,825
Yaedashe	213,480	Sinku	157,383
Kyaukkyi	113,311	Mogok	166,952
Pyu	256,435	Thabeikkyin	127,252
Oatwin	160,054	Tagaung(ST)	35,641
Htantapin	117,662		
		KYAUKSE	739,315
PYAY	910,974	Kyaukse	257,545
Pyay	251,145	Singaing	149,083
Paukkhaung	124,535	Myitthar	195,570
Padaung	145,512	Tada U	137,117
Paunde	137,481	MYINGYAN	1,055,371
Thegon	130,900	Myingyan	276,190
Shwedaung	121,401	Taungtha	216,399
		Natogyi	176,927
THARYARWADDY	1,061,467	Kyaukpadaung	261,800
Tharyarwaddy	150,959	Ngazun	124,055
Letpadan	177,255		
Minhla	122,411	NYAUNG U	239,713
Okpo	126,659	Nyaung U	197,746
Zigon	67,378	Ngathayauk(ST)	41,967
Nattalin	172,122		
Monyo	127,540	AME'THIN	508,000
Gyobingauk	117,143	Yame'thin	248,792
		Pyawbwe	259,208
NAY PYI TAW	1,158,367		
OTTARA	526,068	MEIKTILA	880,802
Tatkon	216,950	Meiktila	309,465
Zeyarthiri	111,256	Mahlaing	139,368
Ottarathiri	81,499	Thazi	202,497
Pobbathiri	116,363	Wundwin	229,472
DEKKHINA	631,325		
Pyinmana	187,415		
Lewe	284,144		
Zabuthiri	109,334		
Dekkhinathiri	50,432		

2.3. Case Studies on HSR Stations in South Korea & Vietnam

2.3.1. South Korea’s Case of HSR Stations

1) Overview

- South Korea has constructed and operated Gyeongbu, Honam and capital-region HSRs, and this case of station planning can be referred to when planning the construction of the HSR in Myanmar.

- Seoul, Busan, Daejeon and Daegu Stations, which are metropolitan stations, are foothold stations for the existing conventional rails, and thus, it was planned to share the existing stations, but the other stations located in medium-sized and large cities were mostly planned to be newly built.
  - If the existing foothold stations are utilized as HSR stations, sites that can be shared such as tracks and platforms required for the operation of the HSR need to be secured. In South Korea, where the existing foothold stations had the sites needed for the operation of the HSR, it was possible to utilize them as stations for the HSR. Also, because the existing conventional rails were of standard gauge, there was the advantage that some tracks could be shared.
  - In the case of HSR stations built in medium-sized and small citities, it was difficult to secure HSR tracks and platforms within the sites of the existing stations or the following problems occurred: operating time delays caused by detouring routes and excessive project costs caused by the mining of downtown rail sections. Thus, the HSR stations were newly constructed at the outskirts of those cities. In many cases, plans for new town development around the new stations were developed.

2) The case of upgrading the existing Daejeon Station

- Daejeon, which is a metropolitan city with a population of 1.5 million, is a foothold station that connects Gyeongbu, Honam and Chungbuk Lines.

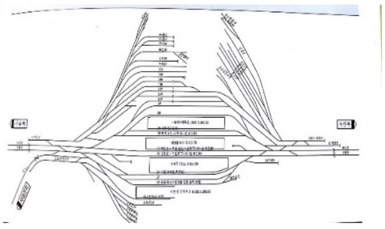
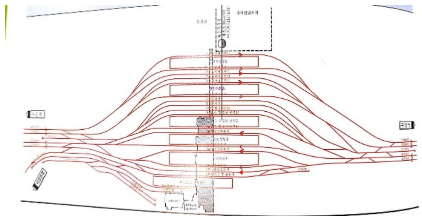
- Beginning from the early stage of the construction, there were a lot of discussions among KRNA, the central and local governments and local residents with regard to the station location and construction method. Due to the delay in the discussions, it was opened the latest of the Gyeongbu HSR route. The method of passing through downtown Daejeon was changed a few times, and on the condition that the central government would provide

the project cost for the maintenance of the surrounding areas of the rail line in the city (such as upgrade of the transportation infrastructure in the areas nearby), it was finally agreed upon that the planned underground line construction would be converted into an above-ground construction.
- 1990 (underground) → 1993 (above ground) → 1994 (underground) → 2006 (above ground)

• The above-ground construction cost including the maintenance project was KRW 1,325.9 billion (USD 11,529 million), which was similar to the underground construction cost of KRW 1,342.6 billion (USD 11,675 million).

• In the station yard, HSR-only tracks and platform facilities were expanded with some sidings reduced.

Table 133 | The Cases of Upgrading the Tracks & Platforms Dedicated to the HSR in Daejeon

Category	Original (Temporary use)	Changed into
Track Layout		
Train/Station	Handling passengers and small freight by HSR and conventional rails Integrated stations of HSR and conventional rails	
Tracks	2 high-speed tracks, 8 conventional tracks and 12 sidings	8 high-speed tracks, 10 conventional tracks and 7 sidings
Platforms	HSR: 1 low platform Conventional rails: 3 low platforms	HSR: 3 low platforms Conventional rails: 3 low platforms

2.3.2. The Case of Reviewing Station Locations for the HSR FS in Vietnam

1) Overview

• In Vietnam, narrow-gauge tracks have been operated as in Myanmar, and in the long term, a HSR construction plan is being developed for the north-south corridor in the country.

• In this chapter, the concept of the feasibility study on the Nha Trang~Ho Chi Minh route in Vietnam will be reviewed in order to use the outcome for the ways of building a HSR in the Yangon~Mandalay route.

Table 134 | HSR Plan for Nha Trang~Ho Chi Minh in Vietnam

<table>
<tr><th colspan="2">HSR Plan for Nha Trang~Ho Chi Minh in Vietnam</th></tr>
<tr><td>
</td><td>• Project name: FS for the Double Tracking of Nha Trang~Ho Chi Minh in Vietnam
• Track length: 412km, 6 stations
• Study period: 2005~2007
• Project scope:
- FS for conventional rails (200km/h) and a HSR (350km/h) in Nha Trang~Ho Chi Minh
- Route, station, roadbed and systems plans
- Transport demand forecast, and economic and financial analyses
• Design criteria
- The design standards for conventional and high-speed rails in South Korea were applied.</td></tr>
</table>

2) Route & Structural Plans

• The route has been planned to be new double track based on a design speed of 350 km/h.

• Basically, the minimum curve radius was 5000 m. And for the entrance parts to downtown stations, the curve radius was reduced to 2,000 m, if inevitable.

• For the typical sections of earthworks, bridges and tunnels, those of the Gyeongbu HSR in South Korea were adopted.

• The train was composed of 10 cars and was capable of double-headed operation.

• The schedule speeds of train operation between Nha Trang and Ho Chi Minh were estimated at about 200 km/h (travel time: 1 hour 50 min.) if there was no intermediate stop, and at 182 km/h (travel time: 2 hours) if there were intermediate stops.

• Two rolling stock depots were planned in Nha Trang and Ho Chi Minh.

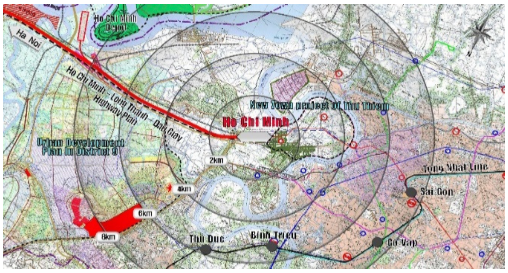
Station Plan

• There are six stations between Vietnam Nha Trang and Ho Chi Minh (412 km) with an average inter-station distance of about 82.4 km. This section has relatively small cities except for Nha Trang and Ho Chi Minh, which are the SP and EP stations, and a low transport demand.

• As the stations were all new, they were located away from the existing stations.

• In the feasibility study for the selection of station locations, development plans for new cities, commercial development plans for station vicinity areas, development plans for new international airports and future development potential were chiefly considered.

Table 135 | Cases of Planning the Stations in Vietnam

<table>
<tr><th>Nha Trang Station</th><th>Ho Chi Minh Station</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>• Located about 3~4 km away from the existing Nha Trang Station.
• New stations were planned in the western area under a development plan and a middle area in the old downtown.
• An integrated operation plan was established by planning the relocation of the passenger sections of the existing station.</td><td>• Located about 7~8 km away from the existing Sai gon Station.
• A new station was planned in an area with the potential of vicinity area development (e.g., the area that has a new town development plan).
• A plan was developed that maximized the potential of future development and the interface with new town development plans.</td></tr>
</table>

2.4. Review of Station Locations

2.4.1. Yangon Station

1) Review of the Existing Station Location

Figure 40 | Present Situation of the Existing Yangon Station

Existing station condition	• The central station in Yangon is located in the center of downtown Yangon, and around the city, residential areas and stores are concentrated. • It is the central station for the Yangon~Mandalay railway and the Yangon Ring Railway and is used by the highest passenger traffic. • Due to a lot of sidings in the station yard, the width is as wide as 160 m, but the length of the station is short as about 650 m. • The curve radius of the main tracks at the entrance to the station is less than 500 m.
Facilities needed for a HSR	• When referring to the track layout in the foothold stations at the start and end points and South Korean cases, - the station needs to be 1.3~1.6km or longer. - Three platforms and six tracks dedicated to a HSR are needed. • Considering the present situation of the existing Yangon Station, although there has been no case of application to Korea's HSRs, the construction of a stub station needs to be reviewed in order to minimize the conflict with the surrounding structures. • The main tracks in the downtown need to be extended to 5,000 m or above (where inevitable, 2000 m).
Problems in sharing	• When providing facilities for the HSR (3 platforms and 6 tracks), large-scale conflicts with the houses and buildings before and after the existing station site are unavoidable. • It is difficult to secure spaces for the installation of storage facilities. -> The operating cost increases due to the night storage in the R/S depot. • It is unavoidable to relocate the MG storage tracks and the maintenance facilities within the existing station,. • If the tracks enter the existing station in parallel with the existing ones in order to share it, it is unavoidable to create a grade separation for roads and conflict with the residential communities around the tracks.

2) Review of Station Location Alternatives

Figure 41 | Review of Yangon Station Location

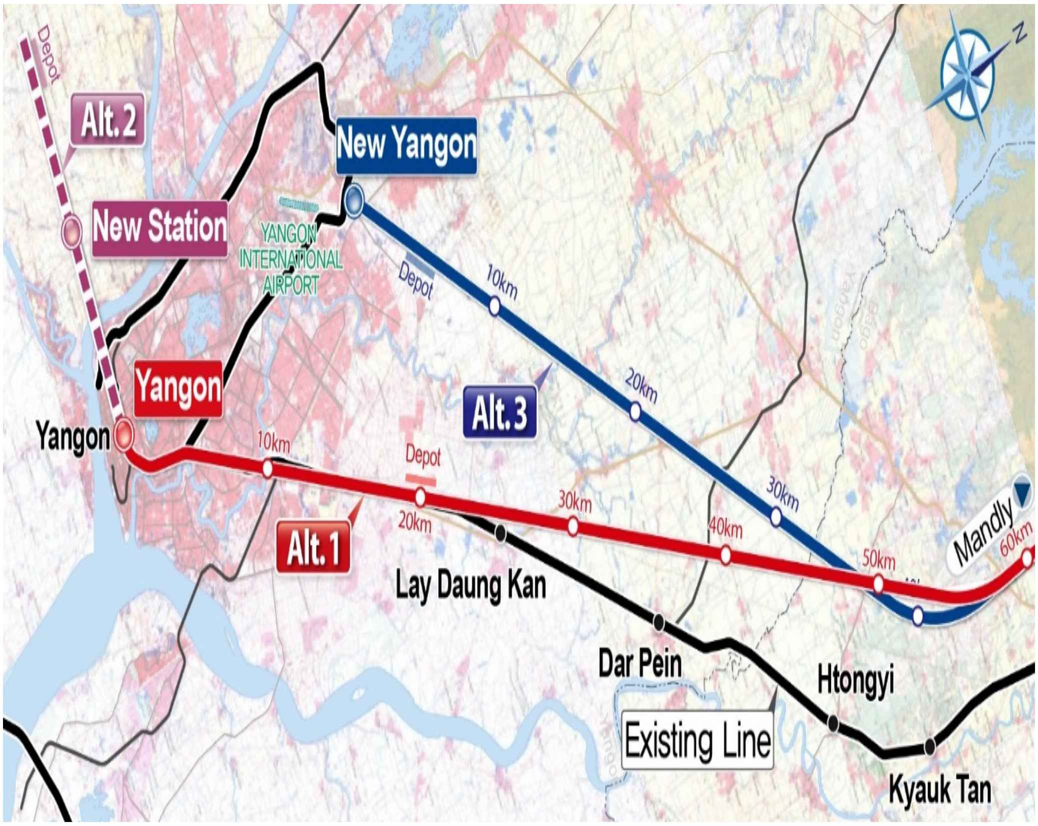
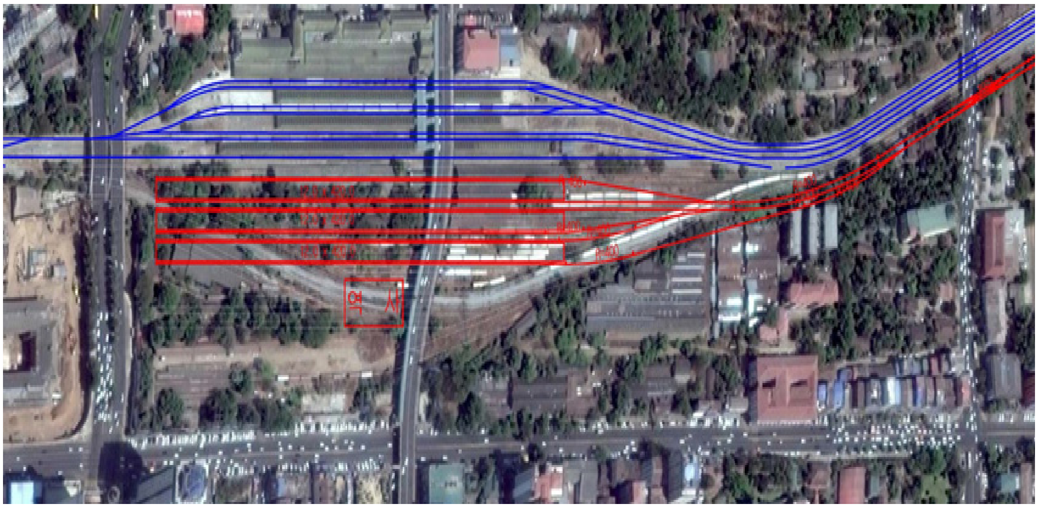


Figure 42 | Plan to Share the Existing Yangon Station for the HSR & the MG Track (Alt 1)



Alt. 1	Facility Overview	• Planning it as the station shared with HSR by expanding and improving the existing Yangon Station • Considering the present condition of the existing station site, it should be planned as a stub station (3 platforms and 6 tracks). • Planning the R/S depot in Ywathagyi between Yangon Station and Bago Station
	Merits	• As located in downtown Yangon, it is good in terms of the transport demand and interface with other modes of transportation. • Large-scale downtown redevelopment, commercial development of station vicinity areas and combined station planning
	Demerits	• Civil complaints are unavoidable due to conflicts with residential areas and commercial facilities around the station and downtown trackside. • The operating cost increases due to the night storage at the R/S depot because of the shortage of night storage facilities. • It is unavoidable to relocate the existing MG storage tracks and maintenance facilities to the outskirts.
Alt. 2	Facility Overview	• Planning the existing central station in Yangon as an intermediate station • Planning the starting point station and the R/S depot in connection with the new town development plan in the west of the Yangon River
	Merits	• As the R/S depot is planned to be just behind the starting point station, the operating efficiency is good. • Demand expansion and the city development in connection with the commercial development of station vicinity areas and the Yangon new town development
	Demerits	• Increase in the construction cost due to an about-15 km extension of the main tracks • Due to the large-scale conflicts with the residential and commercial areas around the station and trackside, civil complaints would be unavoidable.

2.4.2. Mandalay Station

1) Review of Existing Station Location

Figure 43 | Present Situation of the eixsting Mandalay Station

Existing station condition	• Mandalay Station is located at the central downtown in Mandalay, and around the station, residential areas and stores are concentrated, and at the end point, there is Mandalay Palace. • This is the second-best station in transport demand next to Yangon Station in Yangon, and it is the first combined station with commercial facilities above the tracks in Myanmar. • The station is structured chiefly for the passenger traffic, and there is a space available for turnback at the rear of the station. • The length of the station is relatively long (1,200 m), but the width is narrow as about 80 m.
Facilities needed for HSR	• When referring to the track layout in the starting and ending point foothold stations and the South Korea case, - The station needs to be 1.3~1.6km or longer. - 3 platforms and 6 tracks dedicated to the HSR are needed. • Considering the present situation of the existing Mandalay Station, although there has been no case of application to Korea's HSRs, the construction of a stub station needs to be reviewed in order to minimize the conflict with the surrounding stuctures.. • For the main tracks in the downtown, the curve radius needs to be expanded to 5000 m or above (if unavoidable, 2000 m).
Problems in sharing	• As the space is very small, it is difficult to provide the facilities (3 platforms and 6 tracks) required for the HSR. • As it is situated at the end point of the station, it is difficult to extend the HSR to the north (Myitkyina) in the future. • For the sharing of the HSR station, it is unavoidable to conflict with the large-scale residential and commercial areas around the station.

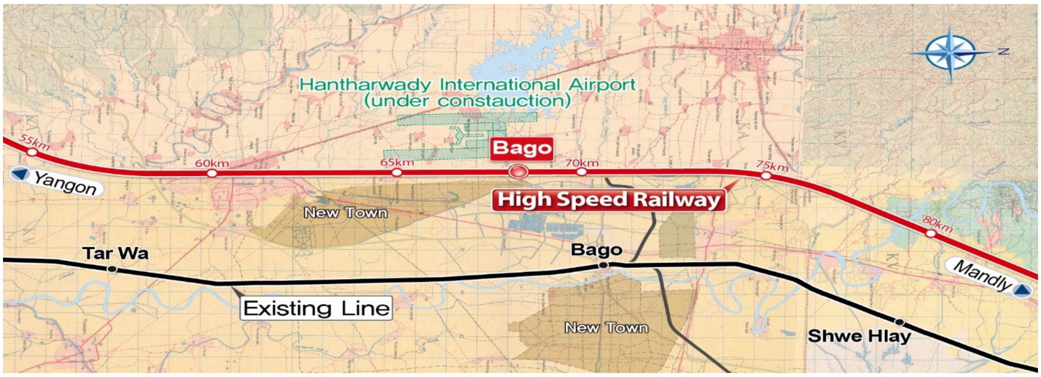
2) Review of Station Locations

Figure 44 | Review of Mandalay Station Location

Alt. 1	Facility Overview	• Expanding and upgrading the existing Mandalay Station and planning it as the starting-point station shared with the HSR • Providing 3 platforms and 6 tracks needed for the HSR operation • Planning the R/S depot in between Kyaukse and Mandalay Station
	Merits	• As it is located in downtown Mandalay, the transport demand and interface with other modes of transportation are good. • Large-scale downtown redevelopment, commercial development of station vicinity areas and combined station planning
	Demerits	• Due to major conflicts with large-scale residential and commercial areas around the station and the downtown trackside, civil complaints are unavoidable. • Increase in the project cost including an enormous compensation cost • It is difficult to extend the HSR to the north (Myitkyina).
Alt. 2	Facility Overview	• Situating the station in an area that requires downtown redevelopment around Myo Haung Station • Planning a R/S depot in between Kyaukse and Mandalay Station
	Merits	• The transport demand is expanded and the interface with other modes of transportation is good as the station is located in the downtown. • Interface with downtown redevelopment, commercial development of station vicinity areas and combined-station planning
	Demerits	• Due to the conflicts with the residential and commercial areas around the station and the downtown trackside, civil complaints are unavoidable. • Project cost increases including enormous compensation cost
Alt. 3	Facility Overview	• Station planning connected with the new town plan in the outskirts • Planning the turnback and R/S depot near the station
	Merits	• Resolving conflicts with large-scale downtown residential and commercial facilities • Reducing civil complaints and drastically saving the construction cost • Promoting new town development and commercial development of station vicinity areas
	Demerits	• Inconvenience in use due to the far distance from the existing downtown and limited expansion of demand • Poor transport system interface with existing rails, buses, etc.

3) Bago Station

Figure 45 | Review of Bago Station Location



Existing station condition	• Bago Station is located in the old downtown Bago, which has not been developed, and there are residential areas and stores around it. • Bago Station has often been flooded due to the low ground. • The passenger traffic is chiefly handled and there are some sidings, but the space is not very wide. • At the start and end points of the station, there are a lot of level crossings and sharp curves.
Problems in sharing	• As the existing station site is small and there are sharp curves and the SP and EP, it is difficult to secure the function of an intermediate HSR station (2 platforms and 4 tracks). • For the station sharing with the HSR, it is unavoidable to conflict with major residential and commercial areas. • Given the frequent flooding, the railway facilities need to be planned to be above the flood level or the river system be improved.
Facilities required for the HSR	• When referring to the track layout in intermediate passing-through stations and the South Korean cases, - The station length needs to be 1.6~2.0km or longer. - 2 platforms and 4 tracks dedicated to the HSR are needed. • For the SP and EP of the station, a curve radius of 5000 m or above needs to be secured.
Alternativ es	• Moving it to a location near the Bago new town as per its development plan and Hanthawaddy International Airport (scheduled to be constructed; and the development authority: Department of Civil Aviation) - Maximizing the mutual-benefit effect by interface between the international airport and the HSR - Enhancing the effect of new town development and commercial development of station vicinity areas and minimizing the project cost

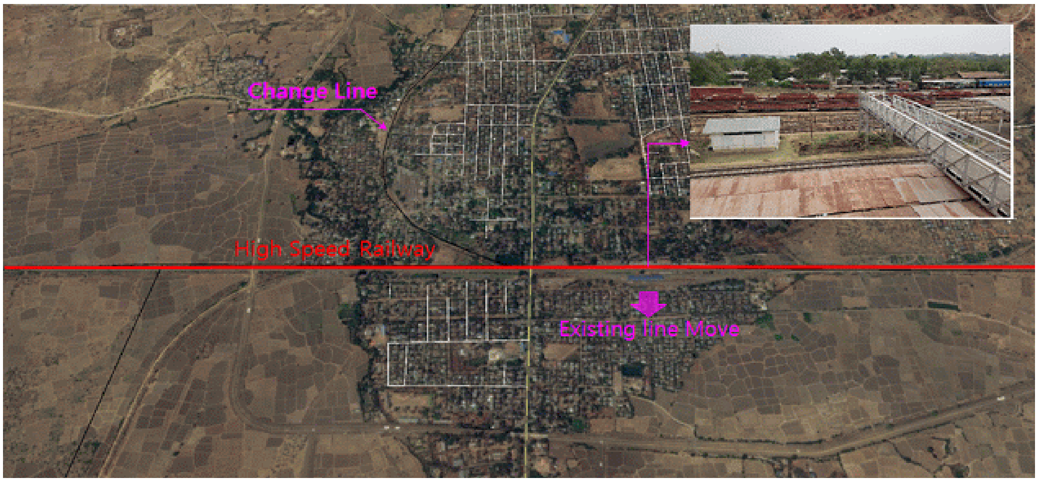
4) Nay Phi Taw Station

Figure 46 | Review of Nay Pyi Taw Station Location

Existing station condition	• Nay Phi Taw Station was opened in 2009 together with the capital city relocation to Nay Phi Taw. • Possessing the best facilities in Myanmar such as track condition and signaling systems • The R/S depot and the R/S manufacturing plant are located adjacent to the existing station. • As the station site is sufficiently wide, it is advantageous to expand the station.
Improvement concept	• Planning the HSR track adjacent to the existing station and relocating the existing tracks (of narrow gauge) to the outside - Operating passenger trains chiefly for the HSR in the future - Considering the convenience in using the R/S depot for the existing narrow-gauge vehicles • Planning it as an intermediate foothold station considering the symbolism of the city as the national capital and the future development potential
HSR facilities	• Platform and track facilities - 3 platforms and 6 tracks dedicated to the HSR • Stations - Creating a combined station including appurtenant facilities such as hotels and department stores or a shared station by upgrading the existing station
Features	• Enhancing the operating efficiency and transport demand through an integrated operation with the existing station • Minimizing the project cost

5) Thazi Station

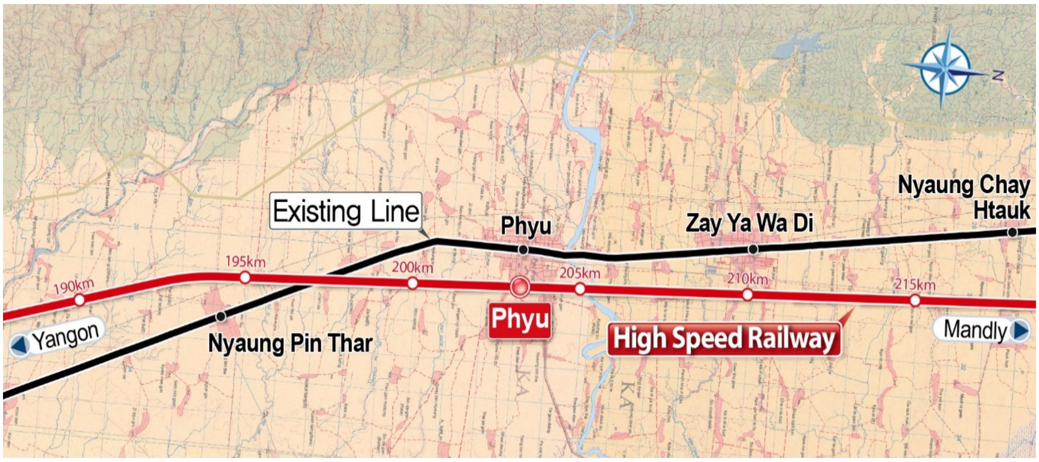
Figure 47 | Review of Thazi Station Location



Existing station condition	• Thazi Station is a foothold station that controls the area from Pyinmana to Thazi Station. • A rail runs from the SP of Thazi Station to Shan State and Magway Division (east-to-west direction in Myanmar). • There are a lot of sidings and a wide yard, and the alignments of the SP and EP are good. • The downtown around the station has not been developed.
Improve ment concept	• Planning the HSR track near the existing station and relocating the existing tracks (of narrow gauge) to the outside - Operating passenger trains chiefly for the HSR in the future • Planning the station as an intermediate passing-through station for the HSR • Considering transfer to/from conventional rails and convenience of use
HSR facilities	• Platform and track facilities: An intermediate passing-through station - 2 platforms and 4 tracks dedicated to the HSR • Station - Planning a shared station by upgrading the existing station • Converting the level crossings into multi-level ones at the SP and EP of the station
Features	• Enhancing the operating efficiency and transport demand through an integrated operation with the existing station • Minimizing the project cost

6) Phyu Station

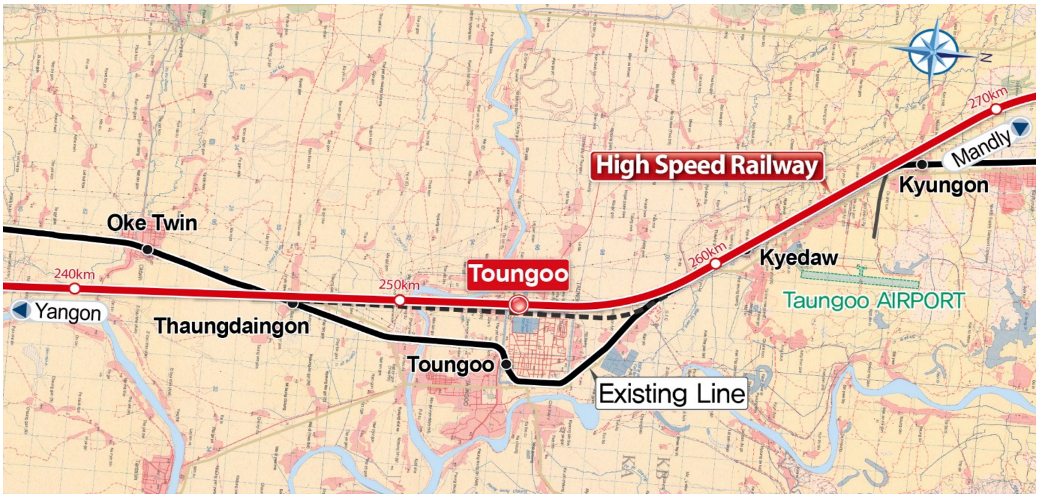
Figure 48 | Review of Phyu Station Location



Existing station condition	• Phyu Station is a passenger-only station with 2 platforms and 2 tracks and the station site is small. • The area is in Phyu Township of Bago Division and has a population of 256,435. • The rail line runs in parallel with a road and there are residential and commercial areas between the road and rail.
Improvement concept	• Planning the station to a location about 1.5 km away from the existing station - The plan is connected with the new town development and commercial development of the station vicinity areas. • Considering an integrated station by relocating the existing rails and enhanced efficiency of use
HSR facilities	• Platforms and tracks - 2 platforms and 4 tracks dedicated to the HSR • Station - Reviewing an integrated station by relocating the existing station - Studying a possible development of an integrated station including appurtenant facilities such as hotels and department stores
Features	• Due to the small site of the existing station and the concentration of residential and commercial areas around the tracks, it is unavoidable to relocate it to the outskirts. • The operating efficiency and transport demand are improved by relocating it so as to be in parallel with the existing rails.

7) Toungoo Station

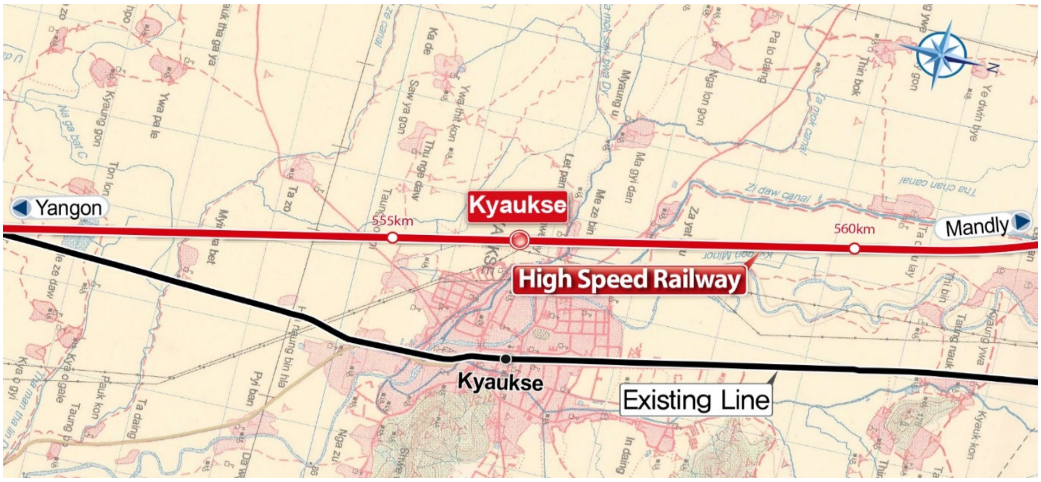
Figure 49 | Review of Toungoo Station Location



Existing station condition	• Toungoo Station is a foothold station that controls the area from Pyuntaza to Pyinmana Station. • Taungoo Station is located on the side of the palace, and the SP and EP of the station are on sharp curves. • With 2 platforms and 6 tracks, the station site is not wide, and in front of the station, there are a pagoda and stores. • It is in Toungoo Township of Bago Division with a population of 261,737.
Improvement concept	• Planning to move the station to a location about 2~3 km from the existing station - Interfacing the plan with the plans for new town development and commercial development of the station vicinity areas • Considering an integrated station through the relocation of the existing rails and an enhanced efficiency of use
HSR facilities	• Platforms and tracks - 2 platforms and 4 tracks dedicated to the HSR • Station - Reviewing an integrated station through the relocation of the existing station - Examining the development of a combined station including appurtenant facilities such as hotels and department stores
Features	• As it is difficult to make the improvements within the existing site due to the small area of the station and its being situated inside the palace, it is unavoidable to relocate it to the outskirts. • Enhancing the operating efficiency and transport demand by relocating it so as to be in parallel with the existing rails

8) Kyaukse Station

Figure 50 | Review of Kyaukse Station Location



Existing station condition	• Kyaukse Station is a passenger-only station with 2 platforms and 4 tracks and the site is small. • It is in Kyaukse Township of Mandalay Division with a population of 257,545. It is an industrial city with lots of factories around the station. • The rail route runs in parallel with the road, and houses and stores are concentrated between the road and the rail.
Improve ment concept	• Relocating the station to a place about 1.5~2.0km away from the existing station - Interface with new town development and commercial development of the station vicinity areas • Enhancing the efficiency of use and creating an integrated station by relocating the existing rails
HSR facilities	• Platforms and tracks - 2 platforms and 4 tracks dedicated to the HSR • Station - Reviewing an integrated station through the relocation of the existing station - Examining the development of a combined station including appurtenant facilities such as hotels and department stores
Features	• Due to the small area of the station and there are residential and commercial areas in high densities around the tracks, it is unavoidable to relocate it to the outskirts. • Enhancing the operating efficiency and transport demand by relocating it so as to be in parallel with the existing rails

2.5. Review of the Commercial Development of Station Vicinity Areas

2.5.1. Overview of the Station Vicinity Areas

- For the HSR stations, projects for the commercial development of station vicinity areas need to be reviewed for the convenience of rail users and local residents. Station vicinity areas are the areas that can be accessed on foot by rail users and can be developed in linkage due to the influence of the significance of the railway station locations.

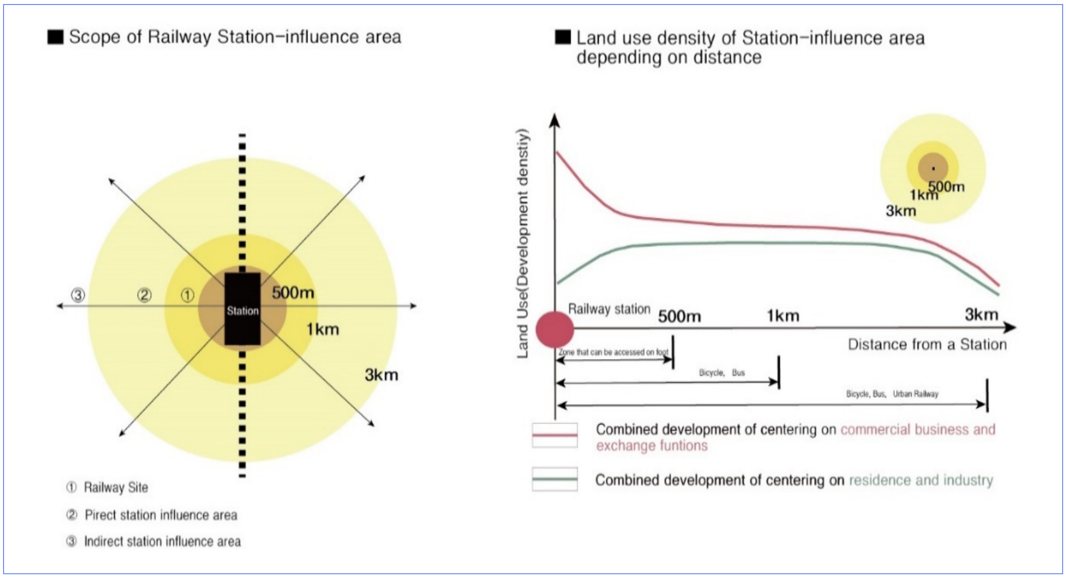
- The vicinity areas of HSR stations are where many HSR users gather and scatter, play the central function of the cities concerned, and serve as the driving force for the maintenance and development of the surrounding areas.

2.5.2. Development Scope of the Station Vicinity Areas (SVA)

Table 136 | Commercial Development Scope & Functions for Station Vicinity Areas

Category	Development Scope	Functions & Development Strategy
Station site	• HSR stations	• Combined transfer center • Transfer system to/from public transportation
Primary SVA	• Within a radius of 500m • Zones that can be accessed on foot	• High-density, combined development with residential and non-residential functions • Centering on commercial business and exchange functions
Secondary SVA	• Within a radius of 500m~1km • Zones that can be accessed on foot by bike and by branch-line bus	• Residential and non-residential functions • Medium-and high-density, combined developments
Areas of rear	• Radius of 1km~3km • Zones where bikes, buses and metro lines can be used.	• Centering on residential or new industrial functions • Medium- and high-density, combined developments

Figure 51 | Scope of Station Vicinity Areas



2.5.3. SVA Development Concepts

- Even in the Yangon~Mandalay HSR construction, SVA development projects are needed that can promote the development for combined uses such as transport, culture, commercial purposes, residential purposes and parks.

- Thus, urban development, transport demand expansion and minimized civil complaints associated with the construction can be pursued by establishing SVA development plans as well as new town development plans.

- Also, it is advisable to reduce the burden of construction cost by collecting some of the profit from the commercial development of station vicinity areas and utilize it for the improvement of the railway operator's profitability.

- In South Korea, too, various types of SVA development have been implemented encompassing high-speed, conventional and metro rails for medium-sized and small cities as well as for metropolitan cities including Seoul and Busan.

Figure 52 | Examples of SVA Development in South Korea

Seoul Station	Osong Station
	
Ulsan Station	Igsan Station
	

2.5.4. Ways of Developing the Station Plan in Myanmar

- Going beyond the simple contact point with the public transportation of metropolitan cities or the simple functions of boarding and deboarding the train, high-speed rail stations serve as a symbol of the region and as an arterial integrated transport center.

- Korea went through ups and downs due to the mixed problems of political decisions on how to pass through the existing major cities and select the locations of new stations and with functional problems of the HSR.

- As Myanmar is using meter-gauge (MG) tracks, there will be difficulties in sharing the existing tracks with the standard-gauge HSR; due to the use of low-numbered turnouts, the length of stations is short; and the alignment condition is not favourable. For these reasons, there are limits in sharing the stations for conventional rails.

- When sharing the representative station, Yangon, for conventional and high-speed rails, the advantages and disadvantages are as follows:

- Due to the interface with the existing transport system including conventional rails, Yangon Ring Rail, and buses between Yangon and Mandalay, there will be a lot of advantages such as convenience of use, increased ridership and the possibility to develop large-scale station vicinity areas for commercial development.

- On the other hand, due to the HSR facilities (3 platforms and 6 tracks), MG track maintenance shops and groups of storage tracks as well as facilities for conventional rails need to be relocated to the outskirts of the city. And the following disadvantages are anticipated to occur: conflict with residential and commercial facilities around the station and the increase in the operating cost due to the night stay and waiting of trains in Ywathagyi R/S Depot.

- In addition, due to the use of SCO turnouts for the entrance to the station, the following problems might occur: limits to reducing operating headways and the whole shut-down of the operation in case of a failure.

- Like this, it is deemed desirable to share the existing Yangon Station from the viewpoint of the convenience of use and increased ridership, but the whole picture needs to be taken into consideration because there are problems such as civil complaints caused by the conflict with the residential and commercial areas in the downtown and the increase in railway operation cost.

- For station planning, a detailed implementation guideline should be created and implemented at the national level by considering the technical aspect, national development plan and local development plans such as new towns in parallel from the initial stage of HSR planning.

- On top of that, it is advisable to alleviate the burden of construction cost through the commercial development of station vicinity areas or to utilize it for the improvement of the railway operator's profitability. Korea has carried out commercial development chiefly for major cities in the country, while Japan has performed the commercial development and urban development based on a broader legal basis.

3. Route Planning

3.1. Overview

3.1.1. Route Selection Overview

- The followings should be taken into account on the basis of the background and necessity of a HSR construction project:
  - Securing a good train operation plan in consideration of the transport demand
  - Compatibility with surrounding-area development plans, structural plans and the station site conditions considering the accessibility to SVAs
  - Securing the connectivity with related plans
  - Balance and technical interface of alignment, and improvement of operating performance
  - Transport systems interfaced with related modes of transportation such as rails and roads
  - Minimizing the conflicts and damages by bypassing cultural asset reserves (royal palaces, pagodas, etc.), military bases, ecological preservation areas and residential area concentration areas
  - Minimizing civil complaints and making project implementation smooth
  - Optimizing the construction cost and time
  - Minimizing social conflicts by collecting the opinions from the central and local governments, local residents, environmental organizations, etc.

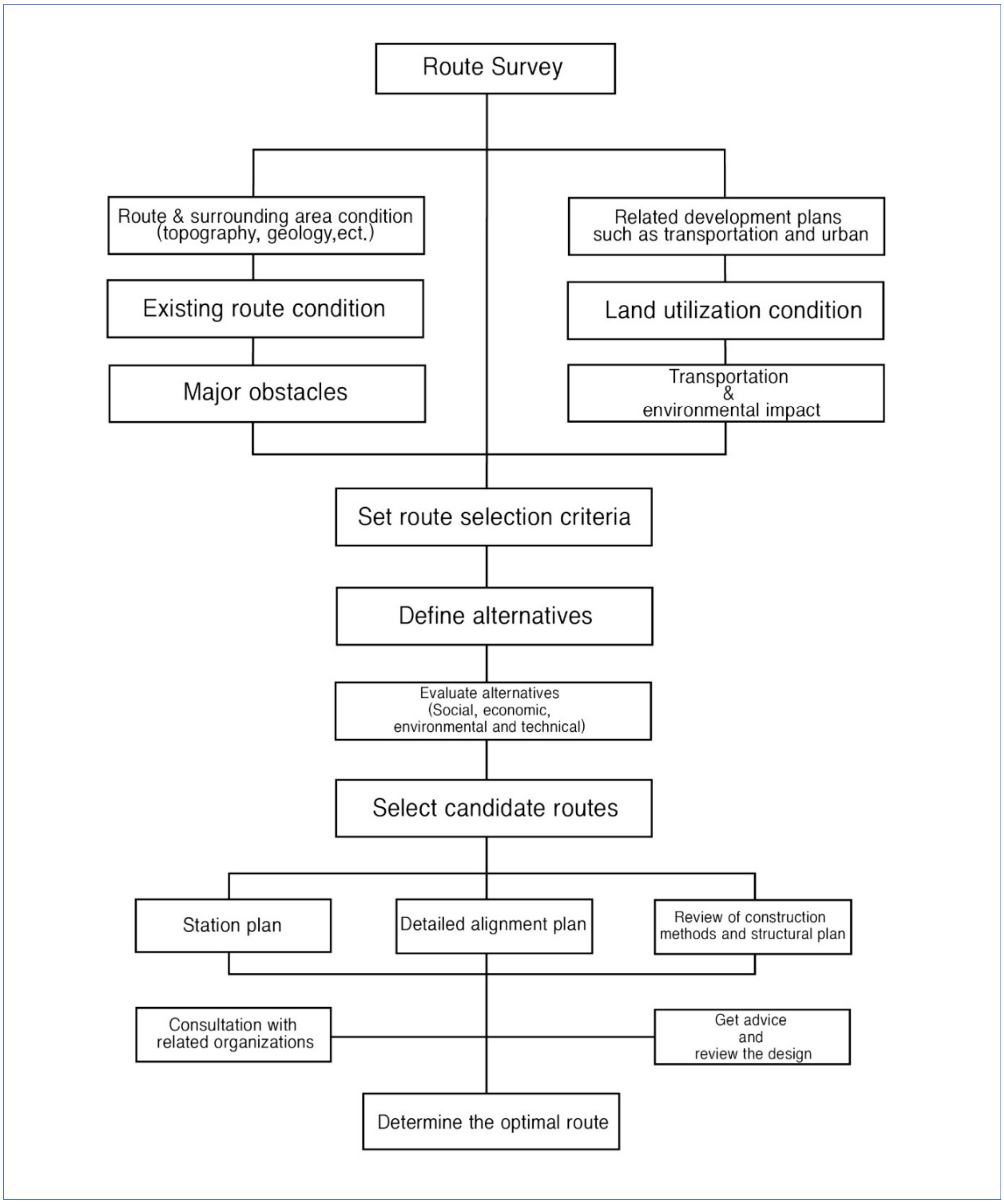
- In this project, to discuss the HSR project with MR, the route corridor considered by MR for the Yangon~Mandalay section has been roughly estimated based on major stations.

- The optimal route plan should be established by selecting various route alternatives considering the national and city development plans and interfaced-transport plans mentioned above at the stages of preliminary and main feasibility studies in the future.

3.2. Route Selection Flow Chart

- The typical route selection process in South Korea is as illustrated below.

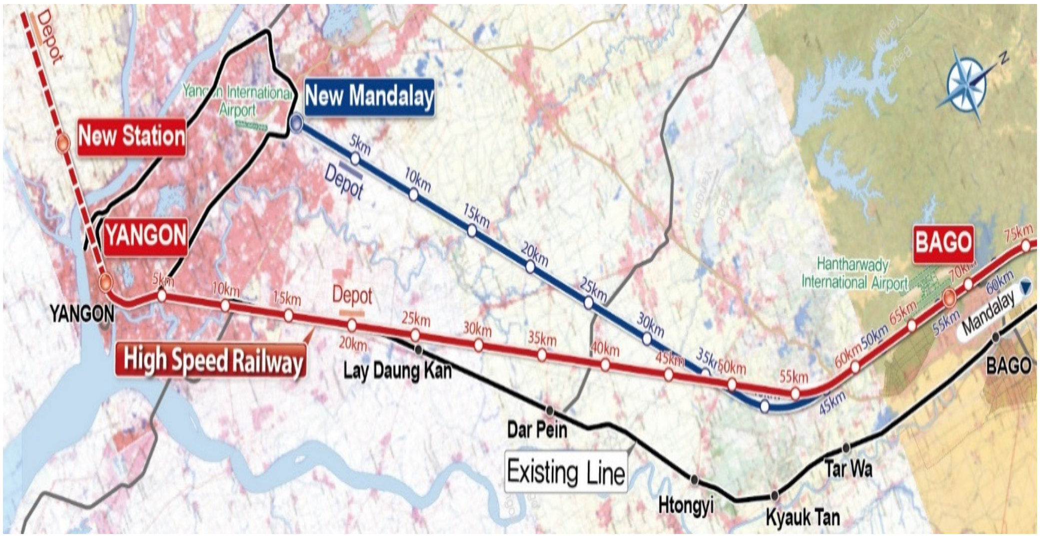
Figure 53 | South Korea’s Route Selection Flow



3.2.1. Route Selection by Section

1) Yangon~Bago Section

Figure 54 | Yangon~Bago Section Route Plan



Existing line condition	• The line connects Yangon Station, the greatest station in Myanmar, to Bago Station or the capital of Bago Division. • In downtown Yangon and Bago there are a lot of sharp curves with a radius of less than 500 m, and houses and commercial districts are concentrated around the line. • Bago is often flooded during heavy rains.
HSR stations	• For Yangon Station, the sharing of the existing Yangon Station (Alt 1), construction of a new station in the west of the Yango River (Alt 2) and construction of new Yangon Station (Alt 3) are being planned. • Bago Station is scheduled to be moved to a location near the planned Bago New Town and Hanthawaddy International Airport.
Route plan	• Connects Yangon Station and Bago Station by the shortest distance. • A planned curve radius of 5,000 m or above - When it is planned to locate it in downtown Yangon (Alt 1 and Alt 2), it is possible to reduce the curve radius depending on the passing speed, but a minimum of 2,000 m is advisable. • Planning the location of the R/S depot as close to Yangon Station as possible • Bypassing the flood-prone areas in Bago

2) Bago~Phyu~Toungoo

Figure 55 | Bago~Phyu~Toungoo Section Route Plan

Existing line condition	• The Bago~Phyu~Toungoo line connects major Townships in Bago Division. • The existing lines connect major villages and their alignments are good except for the curve radii of 500 m or under. • On the left of Bago~Phyu there is Moe Yin Gyi Wildlife Reserve.
HSR stations	• Bago Station is planned to be moved to a location near the planned Bago New Town and Hanthawaddy International Airport. • Phyu and Toungoo Stations are to be relocated to the outskirts of the cities due to the small site of the existing stations, conflicts with cultural asset reserves, etc.
Route plan	• Between Bago Station and Phyu Station, Moe Yin Gyi Wildlife Reserve and the residential-areas concentration zones should be bypassed. • Phyu Station~Toungoo Station should be linked by the shortest route. • The curve radii should be planned to be a minimum of 5,000m. • Considering transport demand expansion and the interface with existing rails, the modification of the existing rail line between Phyu and Toungoo should be examined.
Future plan	• Considering an efficient use of land, constructability and maintainability during the route planning, a route in parallel with an expressway or an existing rail in proximity needs to be studied.

3) Toungoo~NayPyiTaw

Figure 56 | Toungoo~Naypyitaw Section Route Plan

Existing line condition	• Connects Toungoo to Nayphitaw and goes through Toungoo, Yedashe, Lewe, Pyinmana, and PobbaThiri Township. • The existing line links major villages and the alignment is good except for some sharp curves in the entrance to the stations. • As it is about 5 km away from Nayphitaw International Airport, the rail use is inconvenient. • In the case of Pyinmana Station with a large population around it, it is inconvenient to use it as the Yangon~Mandalay express trains do not stop there.
HSR stations	• Toungoo Station is to be moved to the outskirts of the city due to the small site of the existing station, conflicts with cultural asset reserves, etc. • For Nayphitaw Station, a sufficient rail site should be secured, and given the interface with the existing rails, the existing station is planned to be shared.
Route plan	• The route corridor is planned to be in parallel with the existing rail and road with some clearance. • The route is planned to be near Nayphitaw International Airport and Pyinmana New Town so that stations may be built as needed in the future. • The HSR section passing through Nayphitaw Station should be laid out near the existing station, with the existing line arranged on the distant side. - The project cost can be saved due to the crossing and the convenience of using the R/S depot for the existing rails.
Future plan	• The distance between Toungoo and Nayphitaw Stations is longer than 100 km. Considering maintenance, a route plan will be examined in view of the installation of equipment storage

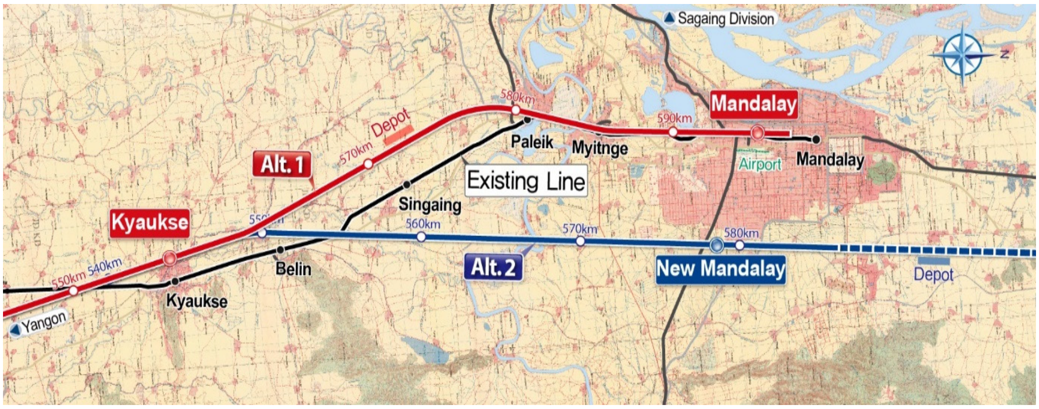
4) NayPyiTaw~Kyaukse

Figure 57 | Naypyitaw~Kyaukse Section Route Plan

Existing line condition	• The line connects Nayphitaw~Thazi~Kyaukse and goes through Tatkon, Yamethin, Thazi, Wundwin, Myittha, and Kyaukse Township. • The existing line connects major villages and the alignment is good except for some sharp curves in the entrance to the stations. • The line goes from the SP of Thazi Station to Shan State and to Magway Division.
HSR stations	• Nayphitaw and Thazi Stations are planned to be shared with the existing stations considering the interface with the existing rails and the securing of sufficient rail sites. • Kyaukse Station is small in its site and residential areas and stores are concentrated around the station. Thus, it needs to be relocated to the outskirts of the city.
Route plan	• The route is the shortest connection of Nayphitaw~Thazi~Kyaukse. • The route bypasses the dense residential areas and runs in parallel with the existing rail and road with some distance. • At the SP of Thazi Station, some parts of the existing rail are to be changed. • Considering transport demand expansion and the interface with the existing rails, the route change for the existing rail in Kyaukse is being considered.
Future plan	• Considering an efficient use of land, constructability and maintainability during the route planning, a route in parallel with an expressway or an existing rail in proximity needs to be studied.

5) Kyaukse~Mandalay

Figure 58 | Kyaukse~Mandalay Section Route Plan



Existing line condition	• Mandalay Station is the first combined station in Myanmar that has a hotel above the rail tracks and commercial facilities. • In downtown Mandalay, there are a lot of sharp curves with a radius of 500 m or under, and residential and commercial areas are concentrated around the line. • The rail is connected from the SP of Mandalay Station east-to-west and to Sagaing. • As Mandalay Palace is situated at the EP of Mandalay Station or a foothold station, it is very limited in rail network connection and expansion.
HSR stations	• As the site of Kyaukse Station is small and residential areas and stores are concentrated around the station, the station needs to be relocated to the outskirts of the city. • The existing Mandalay station is planned to be expanded (Alt 1); Near Myo Haung Station in downtown Mandalay, a station is planned to be built (Alt 2); and in the outskirts of downtown Mandalay, new Mandalay Station is planned to be built (Alt 3).
Route plan	• In the cases of Alt 1 and Alt 2, the route runs in parallel with the existing Kyaukse~Mandalay rail. - The future connections with the HSR toward Myitkina and east-to-west are disadvantageous. - Due to the installation of turnback facilities in the EP of the station and the R/S depot in the outskirts of the city, the operating efficiency is reduced. • In the case of Alt 3, the route goes through Kyaukse Station and leads to New Mandalay Station. - It is advantageous to connect the HSR toward Myitkina and east-to-west. - Due to the installation of the R/S depot near the EP of the station, the operating efficiency is higher. • The curve radius is planned to be a minimum of 5,000 m and where it is unavoidable in the downtown, it may be a minimum of 2,000 m.
Future plan	• The route and station plans will be examined in connection with the development plans of new towns and conventional and metro rail construction plans.

3.2.2. Considerations for the Review of the HSR Route in Myanmar

• The curve radii of the existing tracks are mostly less than 500 m, which are much smaller than the minimum curve radius (5,000 m or above) for the HSR. Thus, there are difficulties in building the tracks in parallel with each other.

• As Myanmar has lots of Buddhist cultural asset reserves, military bases and environmental reserves, the HSR route should bypass them through an extensive survey, in principle. And if the route should go through them inevitably, ways of preserving them and minimizing the impact should be examined.
- At the time of constructing the Gyeongbu HSR for the first time in South Korea, there were a lot of difficulties in selecting the route when the route went through environmental reserves, Buddhist temples and downtown areas, and in some sections, construction was suspended due to lawsuits and civil complaints for several years, resulting in a considerable economic loss.
- Thus, at the time of constructing HSRs for the Honam and the capital region, civil complaints and economic losses were minimized by conducting thorough preliminary studies, environmental impact assessment, archaeological surveys, preliminary review of disaster impacts, and the organization of promotion committees involving all the stakeholders including NGOs.

• Basically, HSR systems have standard track gauge while the existing rails in Myanmar have narrow gauge (1,000 mm). Thus, the sharing of tracks is practically impossible.
- It is possible to install dual gauges for the sharing of standard and narrow gauges, but it is advisable to construct separate lines due to problems such as operating safety and track arrangement efficiency.
- Narrow-gauge tracks mostly use lower-numbered turnouts (#8, #10) and are shorter in their valid lengths while high-speed rails use higher-numbered turnouts (min. #18.5, #26, #46) and their stations are very long due to the need to secure the valid length in order to facilitate the passing of the trains.
- In the case of the stations in major cities such as Yangon and Mandalay, as the downtowns are developed around the stations and the commercial development around the station vicinity areas are performed in advance, the spaces in the existing station sites for the installation of HSR facilities (tracks, platforms, etc.) are in great shortage, and a lot of difficulties are expected in expanding the sites of the stations.

• The outcomes of investigations indicate that areas susceptible to flood, soft ground and earthquake-prone zones are distributed along the Yangon~Mandalay corridor. Thus, these should be taken into consideration when determining the route during the detailed planning.

4. Roadbed Structure Plan

4.1. Earthworks

• When planning the at-grade roadbed, the slope gradients for soil embankments and cuts should be determined by analyzing the components of the soil, features of rock beds, location of the ground water and others.

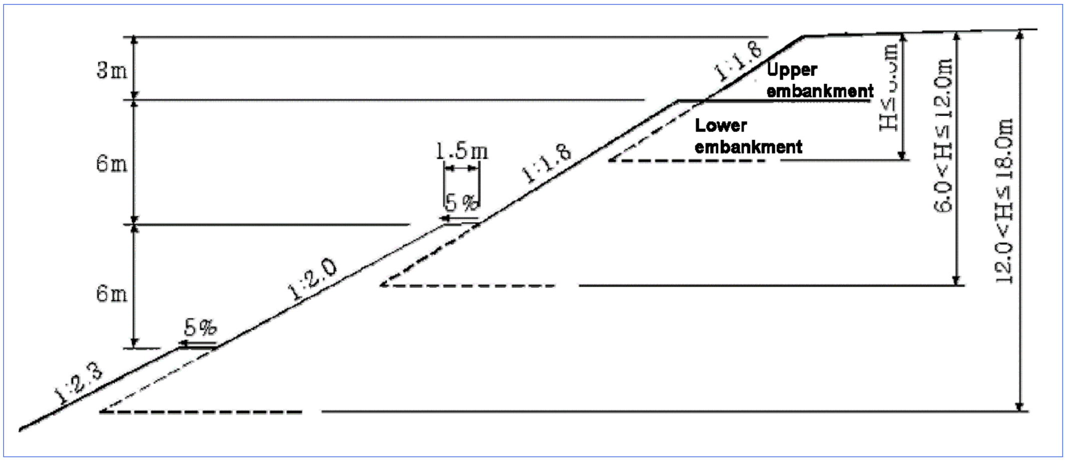
• In this section, the typical gradients and sections of soil embankments and cuts applied to the high-speed rail roadbed of Korea are introduced.

• In addition, the improvement methods for soft ground and the reinforced bases made to secure the running stability of trains and the durability of the roadbed and to increase the bearing power of the roadbed, are presented.

4.1.1. Soil Embankments

• The typical gradients of embankment slopes are as illustrated in the figure below.

Figure 59 | Typical Gradients for Embankment Slopes



Source: KRNA, 'Honam HSR Design Guidelines (Roadbed),' 2007

Table 137 | Typical Slope Gradients Associated with Embankment Heights

Embankment Height (m)	Gradient	Classification of Soil
9m or under	1 : 1.8	Providing a 1.5m-wide berm every 6m of embankment height
9~15m	1 : 2.0	
15m or above	1 : 2.3	

• The section from the formation level up to 3 m is called Upper Embankment, and the section below it is called Lower Embankment.

• As shown in the figure, the typical gradients of embankment slopes from the formation level should be 1 : 1.8 for the height of up to 9 m, 1 : 2.0 for a height of up to 9~15 m, and 1 : 2.3 for a height over 15 m.

4.1.2. Soil Cuts

• The typical gradients for soil cut slopes are as shown in the figure below.

Table 138 | Typical Gradients of Cut Slopes for Different Soil Conditions & Heights

Soil Condition		Slope Height (m)	Gradient	Remarks
Sand			1:1.5 or above	SW, SP
Sandy soil	Dense	Below 5m	1:0.8~1:1.0	SM, SP
		5~10m	1:1.0~1:1.2	
	Not dense and well graded	Below 5m	1:1.0~1:1.2	
		5~10m	1:1.2~1:1.5	
Sandy soil mixed with gravel or rock blocks	Dense and well graded	Below 10m	1:0.8~1:1.0	SM, SC
		10~15m	1:1.0~1:1.2	
	Not dense or poor graded	Below 10m	1:1.0~1:1.2	
		10~15m	1:1.2~1:1.5	
Cohesive soil		0~10m	1:0.8~1:1.2	ML,MH,CL,CH
Cohesive soil mixed with rock blocks or bounders		Below 5m	1:1.0~1:1.2	GM,GC
		5~10m	1:1.2~1:1.5	
Weathered rock		-	1:1.0~1:1.2	Non-forming specimen Rock

Note) 1. Silt is considered as cohesive soil, and other soils than indicated in the table should be considered separately.
2. The gradients as per the table above are those of single slopes not including berms.
3. S (sand), G (gravel), M (silt), C (clay), W (Well graded), P (poor graded), L (low plasticity), H (high plasticity)
Source: KRNA, 'Honam HSR Design Guidelines (Roadbed),' 2007

4.1.3. Reinforced Bases

- Reinforced bases with crushed stone are provided to increase the bearing power of the roadbed and secure its durability and the running stability of trains. They are provided in the at-grade roadbed for main tracks excluding the areas where bridges, tunnels and other structures are constructed, in order to prevent mud pumping of the roadbed, secure the homogeneous rigidity of the roadbed and reduce the repair cycles of tracks.

Table 139 | Thickness of Reinforced Bases

Category	Reinforced Base (mm)		Sum	Section
	Sub-ballast	Mechanical Stabilization		
Embankment	200	200~300	400~500	
Cut	200	200~450	400~650	

Source: KRNA, 'Honam HSR Design Guidelines (Roadbed),' 2007

4.14. Improvement of Soft Ground

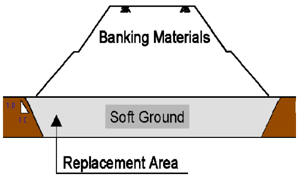
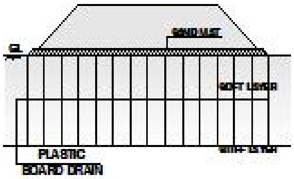
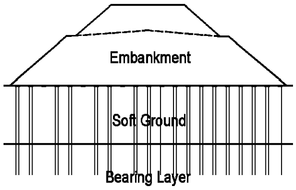
- According to the FS report on the Yangon~Mandalay Railway Rehabilitation & Modernization Project in Myanmar, there are some soft grounds distributed in the project area.

- The soft-ground improvement methods should be selected taking into account site and construction conditions, distribution status of soft ground, construction achievement, the expected effect of the methods, durability, stability and economic performance.

- The improvement of soft ground requires a considerable time, and the construction cost in soft ground is much higher than in normal ground.

- In the case of ballast beds, the permissible residual settlement is 10 cm, and in the case of concrete beds, it is 2.5 cm. Thus, the improvement methods for soft ground are very limited, requiring a considerably increased construction cost. The improvement methods for soft ground are as follows:

Table 140 | Soft-Ground Improvement Methods

Method Category	Replacement	Vertical Drainage	Pile Slab for Supporting a Large Embankment
Schematic Drawing			
Overview	• The soft ground is dug up and replaced with quality materials. This method removes the problem of soft ground fundamentally	• Vertical drainage materials are placed, shortening the drainage distance and accelerating the consolidation in order to improve the ground.	• The load of embankment is transferred to the bearing layer via the piles, securing the ground stability.
Features (Merits & Demerits)	• Fundamental problem solving of soft ground • Easy to construct and lower construction cost • Hard to construct during rainy season and requires drainage • Poor constructability at deeper depth	• Requires a longer period to improve; and it is difficult to fundamentally improve. • Most universal method both in Korea and abroad • Lower construction cost and good constructability • In the case of concrete tracks, it is difficult to meet the permissible settlement standard (2.5 cm).	• Solving problems such as slope stability and settlement of soft ground • A type of ground structure that can definitely secure stability • Higher construction cost • Banking materials might be lost.
Comments & Method Selection	• The replacement method is economical and highly effective when the soft ground layer is lower. • The vertical drainage method is most popular in the case of ballast track, while it is difficult to meet the permissible settlement standard in the case of concrete track. • The pile slab method can definitely secure stability, but its construction cost is very high, and if the embankment is high, it needs to be changed into a bridge type.		

Source: KRNA, 'Basic Design Report,' 2009

4.2. Bridges

4.2.1. Basic Concept of Bridge Planning

- The high-speed rail, which operates at 200 km/hr or faster, should be planned by considering with top priority structural stability such the stability of CWRs (continuous welded rails) and the dynamic stability of trains.

- As recently, earthquakes occurred here and there around the world and there are earthquake-prone areas distributed even in Myanmar, the structural plan should consider the seismic and vibration aspects.

Table 141 | Basic Concept of Bridge Planning

Dynamic stability of trains	• Applying a type that can secure structural stability against dynamic behavior associated with the interactions between the train and the bridge
Composition of span lengths considering CWRs	• As additional stress is caused by the horizontal displacement of the bridge, CWRs are the decisive factor of span composition. • Track stability should be secured by establishing related measures such as the axial-force analysis of CWRs and installation of REJs (Rail Expansion Joints).
Landscape design in harmony with the surrounding environment	• Applying an environment-friendly bridge type in harmony with the surrounding environment • For major cities and national rivers-passing sections, securing the symbolism and the function of landmarks and showing an aesthetic value of shapes and a good view through a good bridge plan
Management of systems interface	• Considering interfaces with roadbed, trackwork, architecture, power transmission and transformation, catenary, power supply, signaling and telecommunications in order to achieve the purposes of easy maintenance and a sufficient persisting period
Reasonable bridge planning through an extensive survey	• Securing the construction gauge for crossing facilities and adopting erection methods by which blocking of traffic flows can be minimized • Incorporating the outcomes of various obstacle surveys, local civil complaints and future plans
Erection method planning considering the surrounding conditions	• Planning temporary facilities considering constructability and economic performance and the erection methods of bridge decks • For river crossing sections, minimizing river pollution

- The landscape plan for downtown-passing sections, zones expected to be developed in the future, and major rivers and roads-passing sections should be established so as to be in harmony with the surrounding environment.

- Besides, the followings shall be taken into full consideration: economic and maintenance aspects, interface with systems, constructability, erection methods considering surrounding conditions, and minimization of the impact of noise and vibration. The basic concept of bridge planning is as follows:

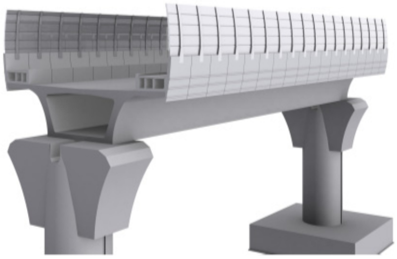
4.2.2. Types of Superstructure

1) Cases of HSR Applications in Korea and Abroad

Table 142 | Types of Superstructure Applied to Korean & Foreign HSRs

<table>
<tr><th>Country</th><th colspan="2">Features of the Bridges Applied</th></tr>
<tr><td rowspan="3">France
(Design speed 350km/h)</td><td></td><td></td></tr>
<tr><td>Tramery Viaduct</td><td>Meuse Viaduct</td></tr>
<tr><td colspan="2">• East-south Line, Atlantic Line: Mostly applying PSC box girder types
• North Line, Mediterranean Line: Applying PSC box girder and composite-steel rationalized plate girder bridges of 50% each
- Spans of 40m or below: PSC box girder, composite-steel rationalized plate girder bridges
- Spans of about 50m: Composite-steel rationalized plate girder bridges</td></tr>
<tr><td rowspan="3">Germany
(Design speed 300km/h)</td><td></td><td></td></tr>
<tr><td>Kassemühle Viaduct</td><td>Gande Viaduct</td></tr>
<tr><td colspan="2">• Mostly applying PSC box girder type, which is easy to maintain
• For bridges with higher piers, applying ILM method and adopting continuous bridges</td></tr>
</table>

<table>
<tr><th>Country</th><th colspan="2">Features of the Bridges Applied</th></tr>
<tr><td rowspan="3">Germany
(Design speed
300km/h)</td><td></td><td></td></tr>
<tr><td>Kassemühle Viaduct</td><td>Gande Viaduct</td></tr>
<tr><td colspan="2">• Mostly applying PSC box girder type, which is easy to maintain
• For bridges with higher piers, applying ILM method and adopting continuous bridges</td></tr>
<tr><td rowspan="3">Spain
(Design speed
250~300km/h)</td><td></td><td></td></tr>
<tr><td>Jalon Viaduct</td><td>Guadalorce River-crossing Bridge</td></tr>
<tr><td colspan="2">• Spans range from 30 to 60 m and the bridges are post-tensioned concrete bridges placed in situ.
- Spans 20~35m long: Hollow slabs
- Spans longer than 40m: PSC box girder bridges
- Where the vertical space under the girder is limited: Through U-type (main span: 41.5m)</td></tr>
<tr><td rowspan="3">Italy
(Design speed
250~350km/h)</td><td></td><td></td></tr>
<tr><td>Modena Br.</td><td>Piacenza Br.</td></tr>
<tr><td colspan="2">• Applying PC types to over 90% of the bridges
• Applying through PSC U girder types to sections with small space under the girders (L=31.5m)
• Applying simple-support bridges to minimize the maintenance cost and not to use REJs</td></tr>
</table>

Country	Features of the Bridges Applied	
Japan (Design speed 250~300km/h)		
	Kurobegawa	Kyshu Shinkansen
	• RC Rahmen viaducts: Excellent in economic performance and the rigidity required for high-speed running of trains; With spans of 10 m each, blocks consisting of 3~6 spans (30~60 m) are laid out. • PC box girder bridge / PC through U-type bridges (L=40~65m)	
South Korea (Design speed 350km/h)		
	Jalon Viaduct	Guadalorce River-crossing Bridge
	• PSC box girder bridges, which are excellent in dynamic behavior and the running stability of trains, take up 95% of the entire bridges. - Geyongbu HSR: 2@40, 3@25m; Honam HSR: 1@30m, 1@35m, 1@40m • For road and obstacle-crossing sections, partially applying composite-steel, rationalized plate girder bridges, arch bridges and truss bridges, which are easy to erect	

2) Proposed Bridge Types

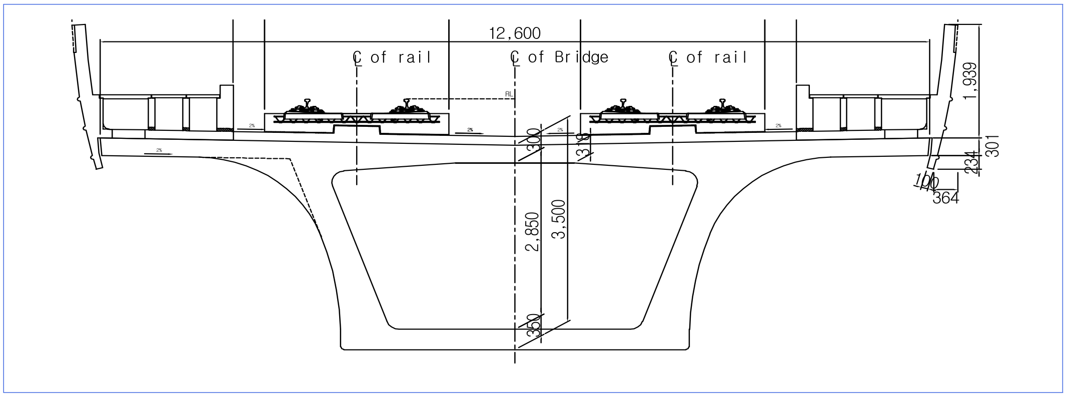
• In South Korea, there were trials and errors such as the following fluctuations in selecting the type of bridge superstructure due to the lack of technical understanding about the dynamic features of a high-speed rail at the initial stage of HSR construction: selecting PSC box type (using the type applied in Germany) to PSC beam type (to reduce the project cost) and back to PSC box type (securing dynamic safety).

• After that, for Gyeongbu HSR Phase 2, Honam HSR, and capital-region HSR, more optimized bridge plans were established based on the analytical technology for bridge-track interactions and independent review of dynamic stability.

• For the type of HSR bridges in Myanmar, PSC box type is deemed appropriate that has been verified in its structural stability as shown in a lot of application cases in Korea and abroad and that has the features of cross-section advantageous to securing usability and dynamic stability, which is a requirement of a HSR bridge.

• The figure below is a typical section of a PSC box bridge for the Honam HSR, which has taken into account structural stability such as structural dynamic stability and bridge-track interactions, interfaces among power supply, signaling and telecommunications and the landscape view.

Figure 60 | Typical Section of a PSC Box for the Honam HSR



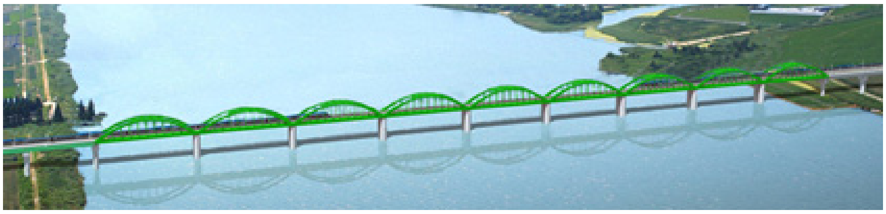
Source: KRNA, ‘Honam HSR Basic Design Report,’ 2007

3) Types for Long-span Sections

• The types need to be determined considering various aspects such as harmony with the surrounding view and the landmark of the region as well as structural safety against CWR-bridge interactions and dynamic safety.

• Bridge types generally applied to bridges with long spans are as follows:

Table 143 | Comparison of Types of Long-span Rail Bridges

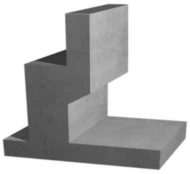
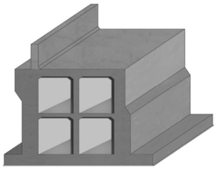
Category	View & Features (Example)
Through Arch	
	• Excellent in scenic view and symbolism; Applied to Gyeongbu, Honam and other HSRs in South Korea. • As simple bridge type is possible to adopt without any need of REJs, it is good to maintain the rails.
Through Truss	
	• Applied to a lot of conventional rail bridges. • As simple bridge type is possible to adopt without any need of REJs, it is good to maintain the rails.
PSC Box	
	• Highly durable; easy to maintain; and lower levels of noise and vibration. • As a continuous bridge type with long spans, it is inevitable to install REJs → disadvantageous to maintenance
PSC Box+ EXTRADOSED	
	• A type in between PSC box and suspended bridges, which is excellent as a symbol. • As a continuous bridge type with long spans, it is inevitable to install REJs → disadvantageous to maintenance

Source: Ministry of Land, Infrastructure & Transport of Korea, 「Dodam~Youngcheon Double-track Metro Master Plan for Jung-ang Line」, 2011

4.2.3. Substructures

- Generally as types of abutment, there are reverse T type and Rahmen type.

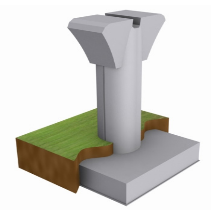
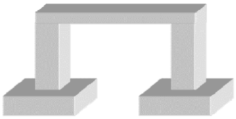
Table 144 | Comparison of Abutment Types

Type	Reverse T Type	Rahmen Type
Section View		
Features	• The dead weight of the structure is reduced and stability is maintained by the weight of soil. • Highly constructible and good compaction conditions • Easy to utilize formworks and to place concrete	• Highly resistant against the horizontal force of the superstructure • Applied to high embankments and road-crossing parts; and easy to maintain. • A little disadvantageous to construction
Application Conditions	• Sections with short spans and lower longitudinal load	• High embankments and sections with higher longitudinal load

4) Types of Pier

- Types of pier are determined considering type of superstructure, structural stability, usability, constructability and economic performance.

Table 145 | Comparison of Pier Types

Pier Type	Hollow T Type	Π Type	Composite Portal Type Rahmen Pier
Section View			
Features	• Single post type with an excellent sense of openness • Advantageous to securing foundation bearing power due to the reduced dead load of the pier	• Suitable to multi-post girder bridges • Advantageous to seismic load • Due to standardized pier types, constructability is higher.	• With the same sectional specification, the spans can be made longer. • Little restriction in the space under the bridge

4.2.4. Foundation Types

- Basic concept for the selection of bridge foundation types is as illustrated below.
- Bridge foundation types can be largely divided into spread foundations (shallow foundations) and deep foundations, and the concept and application standard of each of them are as follows:

Figure 61 | Basic Concept for the Selection of Bridge Foundation Types

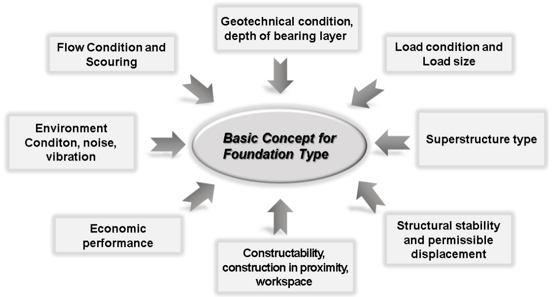
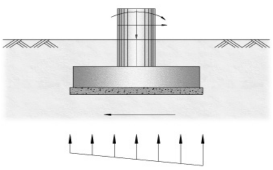
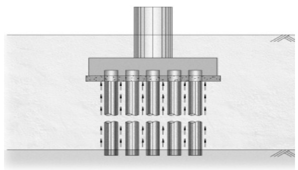
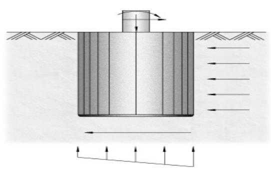


Table 146 | Comparison of Bridge Foundation Types

Foundation Type	Spread Foundation	Deep Foundations	
		Pile Foundation	Caisson Foundation
Load supporting concept			
	• Vertical forces: Bottom reaction • Horizontal forces: Shear resistance of bottom face (friction resistance)	• Vertical forces: Shear, main-face friction resistance • Horizontal forces: Passive resistance of the surrounding ground, bending rigidity of piles	• Vertical forces: Bottom reaction • Horizontal forces: Side reaction & shear resistance (friction resistance)
Div. of Methods	• Single foundations • Combined foundations • Mat foundations	• Driven piles • Bored piles • Drilled shafts	• Open caissons • Pneumatic caissons
Application Standard	• Foundation depth: about 6.0m • There should be no obstacles within the influence zone of the excavation, and it should not be difficult to drain water during construction.	• Foundation depth: 6~60m • Precast piles and drilled shafts are applied depending on field and load conditions.	• Foundation depth: 6~30m • Applied to structures with great vertical load. • Applied to areas to which pile foundation types are not applicable such as areas above riverbeds or under the water.

4.3. Tunnel Plan

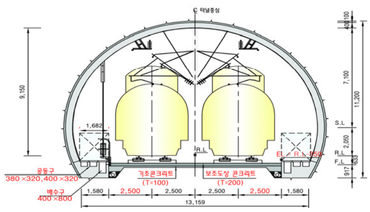
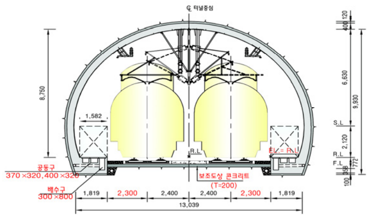
4.3.1. Cross-section of Tunnels

- It is better to construct a tunnel with a larger cross-section in the aspect of train operation safety and passengers' comfort, but the larger the cross-section, the higher the construction cost.

- The optimal cross-section plan that can meet stability, comfort, and economic performance is required, and by studying aerodynamic features, safety assurance through disaster prevention and interface efficiency, the optimal cross-section should be selected.

- Korea's cases of applying tunnel cross-sections to high-speed rails are as follows:

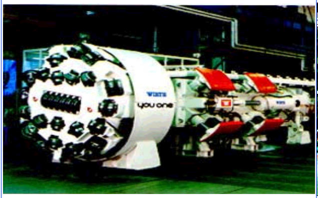
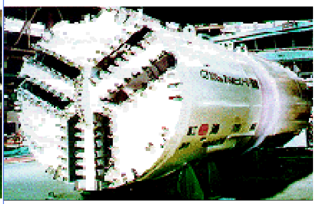
Table 147 | Korea's Cases of Tunnel Cross-sections Applied to HSRs

Item	Gyeongbu HSR	Honam HSR
Schematic drawing		
Track center distance (mm)	5,000	4,800
Height of the inner hole of a tunnel (mm)	R.L.+9,050 (Pulley-type automatic tension controller)	R.L.+8,750 (Spring-type automatic tension controller)
Cable trough	380 × 320 + 400 × 320	370 × 320 + 400 × 320
Lid of a cable trough	4-point support method	3-point support method
Drain (mm)	400 × 800	300 × 800
Height of sidewalk (mm)	R.L.-350	R.L.-0
Track center~sidewalk clearance (mm)	2,500	2,300
Thickness of sub-ballast (mm)	250 (Phase 1)	200
Foundation concrete	Placed	Not placed
Sectional area of the inner hole (㎡)	107	96.7
Cross-sectional area of excavation (㎡)	138	122

4.3.2. Tunnel Drilling Methods

- Tunnel drilling methods can be divided into blasting and mechanical methods. In South Korea, for most tunnels constructed in mountainous areas, NATM method that employs blasting has been applied. For some downtown metro systems, TBM method has been applied for the purpose of preventing noise and vibration.

Table 148 | Comparison of Tunnel Drilling Methods

Category	Blasting Method	Mechanical Methods	
		TBM Method	Shield Method
Overview	• This is the most common drilling method. After boring and blasting, drilling is made while performing supporting works such as shot-crete, rock bolts and auxiliary methods.	• Using a heavy-duty TBM, the front face is drilled or after drilling a pilot tunnel of a small diameter, it is drilled into a larger hole by NATM to make a tunnel.	• For muck handling, a conveyor system is equipped in a steel cylinder with cutter heads, and a tunnel is made by assembling segments at the rear.
Photo			
Merits	• There is a long history of application and the degree of skillfulness is good. • Possible to cope with geotechnical conditions and sectional changes elastically. • • Easy to cope with alignment changes • Simple construction equipment • Constructability and economics are good.	• There is little loosening of the original ground and the quantity of supports can be reduced. • As there is no pollution caused by vibration, gases, etc., the working environment is good and there is little room for civil complaints.	• As this is a mechanical drilling method, noise and vibration are not serious. • Little occurrence of over-breaking • As the cross-sections are closed using segments after drilling, stability improves.
Demerits	• A little complicated process. • A lot of over-breaking • The area of loosening is increased by the impact of blasting. • Civil complaints by noise and vibration during blasting • Poor working condition in the gang due to gas and dust after blasting	• Disadvantageous to coping with the change in geotechnical conditions • In the case of a heavy-duty TBM, it is difficult to change the sectional area and unnecessary spaces occur. • Large work places and large-capacity powering systems are needed. • Preparatory works and higher construction cost	• As the cross-section is round, unnecessary space occurs. • For driving works, a vertical shaft or a platform is required. • If there are obstacles, it is not easy to cope with them. • If the machine fails, construction delays occur. • Higher construction cost • Lower drilling efficiency for soft and hard rocks

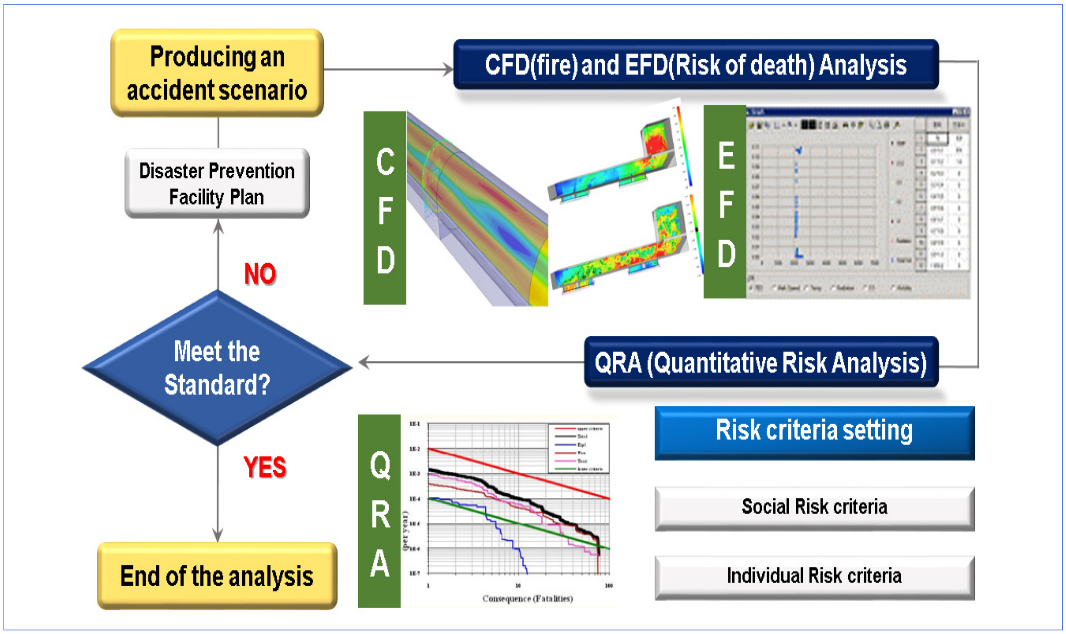
4.3.3. Tunnel Disaster Prevention Plan

• In South Korea, simulations based on applicable laws and rules are carried out and in accordance with the outcomes, a disaster prevention plan should be established so that passengers may evacuate safely in an emergency such as a fire in the tunnel.

• A safety facility plan shall be established based on technical standards of railway structures and Railway Safety Act and through simulations.

• The schematic diagram of a tunnel disaster prevention plan is illustrated below.

Figure 62 | Overview of a Tunnel Disaster Prevention Plan



• Tunnel disaster prevention facilities are classified into accident prevention, evacuation, rescue, fire fighting, and accident reduction.

Table 149 | Division of Tunnel Disaster Prevention Facilities

Accident Prevention	Combustion preventing facilities	Tunnel structures, in-tunnel electric installations
	Train operation control system	Safety switches
	Emergency communication equipment	Mobile phones, train radio and telephones for emergency contacts
Evacuation	Tunnel evacuation passages	Vertical and inclined shafts and shelters
	Other facilities for evacuation	Exit routes, connection parts between main tracks and exit routes, emergency lights, guiding lights or guiding signs, exit passages, opening and closing devices of exit doors, and evacuation stairs
Rescue	Infrastructure for rescue	Access roads to entrances/exits of main line tunnels, disaster prevention and rescue areas
	Facilities for rescue	Electric outlets, signposts
Fire Fighting	Fire extinguishers	
	Department standpipe system	Pipes, fire extinguishing water reservoirs, discharge outlets, and pressurized water supply systems
	Rescue platforms	
Accident Reduction	Smoke control facilities and ventilation	Smoke control, smoke eliminating and ventilating facilities
	Fresh air suppliers	

5. Track & System Plan

5.1. Trackwork

5.1.1. Trackwork Review

- Trackwork is selected considering the burden of tracks caused by the increase in design load, the progression of bed settlement and the quantity of repairs, train running safety and riding comfort, vibration features that affect each member of trackwork and the like.

- The merits and demerits of ballast and concrete tracks applied to Korea’s high-speed rails are as follows:

Table 150 | Merits & Demerits of Ballast & Concrete Tracks

Category	Ballast Track (Gyeongbu HSR Phase 1)	Concrete Track (Gyeongbu HSR Phase 2, Honam & Capital-region HSRs)
Photo		
Merits	• Long-time proven technology. • The replacement of component members is very simple. • Simple adjustment of track alignment is possible (accommodating a larger displacement of the sub-grade). • Alignment change is relatively easy. • Good drainage and elasticity, and noise reduction effect	• Bed tamping repair works are unnecessary. • Continuously maintaining the track alignment and providing high running safety and riding comfort • Little risk of track buckling • The FL~RS bed level is low and its dead weight is small, so that it is possible to reduce the sectional area of structures.
Demerits	• Due to track irregularities, riding comfort is low and periodic and special repair works are needed. • Limited transverse resistance (alignment condition is not favorable and the risk of track buckling exists.) • Relatively heavy and high trackwork • For construction, large-scale facility depots and equipment are needed.	• Surface noise reflection is relatively high. • When cant is changed due to the future speed-up, there are a lot of difficulties. • The range of accommodating the settlement that can occur in an earthwork section is small.

5.1.2. Ballast Track Application Cases & Problems

• Gyeongbu HSR Phase 1, which was opened in 2004, consists chiefly of ballast tracks (most of the 281 km track between Seoul and Daegu), and concrete tracks were laid over about 27 km only for tunnels longer than 5 km and trains have been running on them.

• When applying ballast tracks, there have been cases in which the following problems occurred:
- Differential settlement caused by the difference in rigidity of structural approach blocks
- Damages to rolling stock and facilities caused by gravel scattering by train wind
- Loosening and settlement of tracks at bridge expansion joints

- It is difficult to secure a sufficient time of shut-down for repairs and maintenance personnel with expertise.
- Track buckling caused by the rise in rail temperature during summer and loosening of ballast
- Due to the increase in train operation frequencies and the occurrence of ballast loosening caused by high-speed running of vehicles, periodic measurement and repairs are needed.

Figure 63 | Problems of Ballast Track of Gyeongbu HSR Phase 1 (Seoul~Daegu)

		
〈Gravel scattering〉	〈Damage by gravel scattering〉	〈Rail face damage〉
		
〈Wheel damage〉	〈Frozen bottom of a car body 〉	〈An ice dropped from a vehicle〉

Source: KRNA, 'Honam HSR Osong~Iksan Track Laying Detail Design,' 2012

5.1.3. Concrete Track Cases & Problems

• Maintenance-free track facilities have been pursued continuously in advanced countries with railways such as Germany, France and Japan since the 1960s. They have developed newly-upgraded systems in line with the roadbed structures for major arterial rails, metropolitan metro systems and high-speed rails so as to be compatible with their respective national environment.

• In South Korea, Korean style concrete trackwork called KCT-II was developed beginning from Gyeongbu HSR Phase 2 and has been applied with its trains currently being operated.

- In the past, concrete tracks were applied only to tunnel sections in which it was difficult to maintain the tracks, but recently, they have been used to the entire route including at-grade and bridge sections as well as tunnel sections.

Figure 64 | Concrete Tracks in Gyeongbu HSR Phase 2

		
KCT-Ⅱ on at-grade roadbed	KCT-Ⅱ on a bridge	KCT-Ⅱ in a tunnel

Source: KRNA, 'Honam HSR Osong~Iksan Track Laying Detail Design,' 2012

Figure 65 | Concrete Tracks Laid in At-grade & Bridge Sections in Foreign Countries

		
Rheda2000 on an at-grade roadbed	Rheda2000 on a bridge	J-Slab on a bridge

Source: KRNA, 'Honam HSR Osong~Iksan Track Laying Detail Design,' 2012

- One of concrete tracks' demerits is that a very high cost of roadbed improvement construction or a cost of additional bridge construction are required to meet the residual settlement standard (25 mm) of tracks in addition to a high track construction cost. Furthermore, in the case that differential settlement takes place, structural maintenance is very difficult.

5.1.4. Ways of Application to Myanmar

- In the case of concrete bed, the initial investment cost is high, but it is advantageous in terms of improvement in track safety, maintenance and riding comfort. Thus, South Korea and other countries with advanced railways have recently applied concrete beds.

• Even in the case of Myanmar, it is advisable to apply concrete tracks, if the enormous roadbed construction cost does not increase due to the distribution of large-scale soft ground.

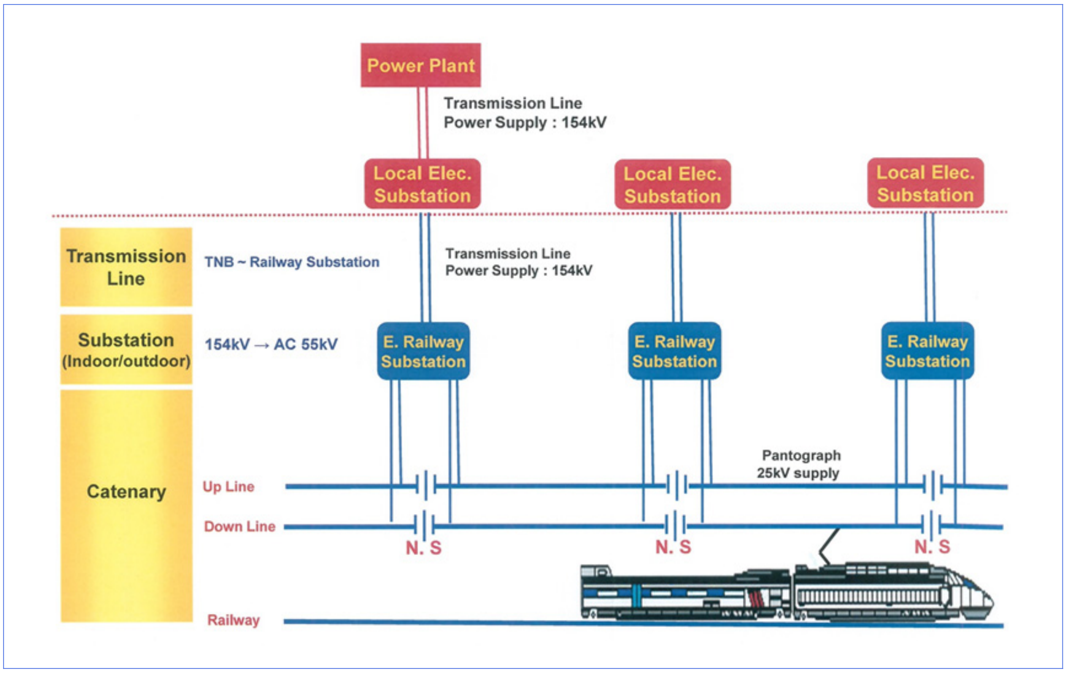
5.2. Electrical Facilities

5.2.1. Overview of Electrical Facilities

• High-speed rails are electrified, in principle, and for the operation of electric rails, power transmission lines, transformation systems, catenary and power supply facilities are required.

• Electric power supply methods may vary with countries, and in this section, Korea's power supply method will be introduced.

Figure 66 | HSR Power Supply System Overview



Source: KRNA, http://www.kr.or.kr/sub/info.do?m-06120403

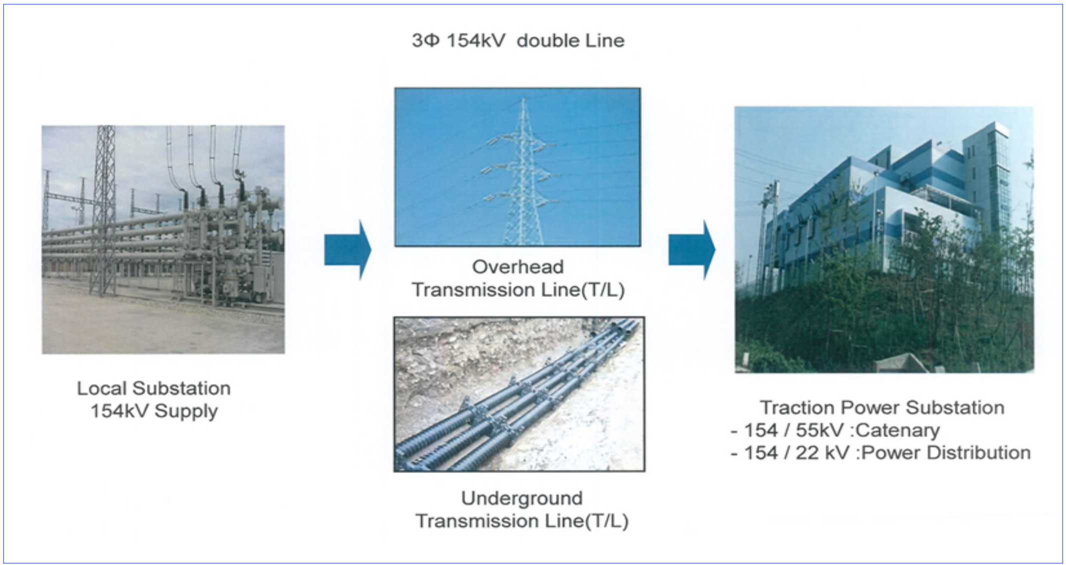
5.2.2. Incoming Transmission Line

- The locations and supply capacities of the substations around the route are investigated; substations that can supply power over the shortest distance and whose reliability in power supply is high are selected; and the optimal power transmission system is designed.

- Incoming power voltage should be selected considering the capacity of the substation, and in order to ensure a stable power supply, two-line incoming method is applied, so that in the event that one incoming line fails, the other one can take over immediately for a normal power supply.

- If incoming power lines pass through mountainous or remote areas, an overhead transmission line, which is economical, is applied, and if they pass through downtown or structures-crossing areas, an underground transmission line is applied.

Figure 67 | Transmission Line Overview



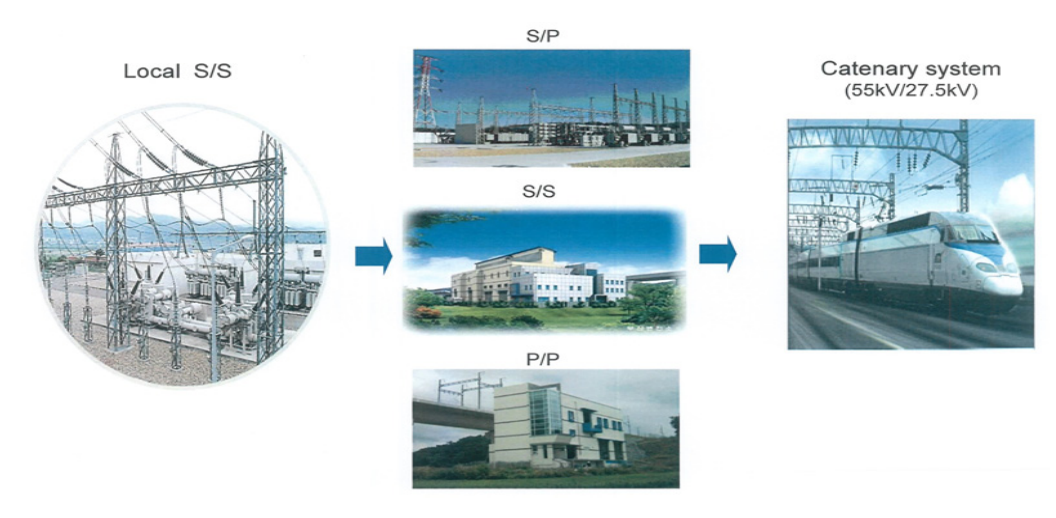
Source: KRNA, http://www.kr.or.kr/sub/info.do?m-06120403

5.2.3. Substations

- In South Korea, given the power distribution capacities for high-speed rails, scott connection transformer method is adopted for supplying power to the high-speed railway operation.

• For the intervals of power supply substations by voltage drop, 50~80 km is applied.

Figure 68 | Substation System Overview



Source: KRNA, http://www.kr.or.kr/sub/info.do?m-06130303

• For systematic operation, management, supervision and control of high-speed rail substations, SCADA systems have been established and operated.

Figure 69 | SCADA System

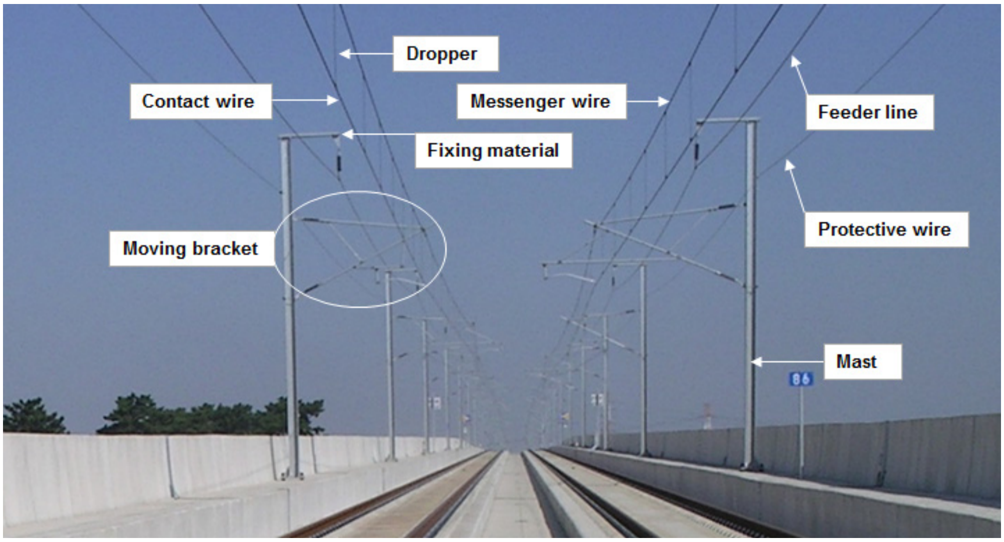
Source: KRNA, http://www.kr.or.kr/sub/info.do?m-06130303

5.2.4. Catenary Systems

- For catenary installation methods, in the case of spans of 50 m or less, high-tension simple catenary method is adopted, and in the case of spans longer than 50 m, Y-stitched simple catenary method is applied.

- For the catenary installation for high-speed rails (a maximum speed of 350 km/h), high-tension simple catenary and Y-stitched simple catenary methods, which utilize pre-sag, are generally adopted.

Figure 70 | Catenary System Compositio



Source: KRNA, http://www.kr.or.kr/sub/info.do?m-0610020602

5.2.5. Power Supply Systems

- A power supply system refers to a system that supplies quality power to electrical facilities in various systems, roadbeds and tunnels efficiently and economically.

- For the power distribution for high-speed rails, 22㎸-△ (or high-resistance grounding) system is used considering track circuits for signaling, telecommunication lines, electric power load capacities, line voltage drop, and compatibility with other power supply systems.

- Power distribution lines are the ones that supply electric power to the stations throughout the high-speed electrified rail line and wayside ancillary facilities, and are composed of power distribution lines dedicated to the underground lines along the trackside.

- Station power supply systems consider a method of receiving power via dedicated lines from KEPCO's substations around the line and high-speed rail power distribution lines.

- The power for tunnels is received via power distribution lines and consists of two-circuit lines in preparation for the failure of the ordinary power supply.

5.3. Power Demand & Supply

- As high-speed rails are operated by electric power, measures for stable power supply are required.

- According to U.S. Energy Information Administration (https://www.eia.gov/beta), the electric power generation in Myanmar in 2014 was 13.75 billion kwh, of which hydro generation is more than 62%, and it is a structure vulnerable to the fluctuation in rainfall. For information, South Korea's electric power generation in 2014 was surveyed to be 513.3 billion kwh.

- The Government of Myanmar announced an electric power system expansion plan of 20 billion USD, focusing on the construction of power generators of 144 billion kwh until 2022, in order to solve the chronic power shortage problems resulting from the increase in electric power demand in 2012.

- The power consumption required for high-speed rail operation varies with line length, track condition and rolling stock, but by referring to the Gyeongbu HSR's electric power consumption, the power consumption of the Yangon~Mandalay has been estimated.

- In South Korea, the power consumption required for Gyeongbu HSR (408 km) is estimated at about 13,871kwh per way (one-time operation per way), which can be converted into about 34 kwh per km.

- If this is applied to the Yangon~Mandalay section, it is estimated at 1.2 billion kwh (≒ 34 kwh x 596 km (track length) x 162 times (round trip, in 2040) x 365 days), which is equal to about 9% of Myanmar's power generation in 2014 and about 0.8% of the estimated electric power generation in 2022, 157.75 billion kwh (= 13.75 billion kwh + 144 billion kwh).

• As the construction of the high-speed rail in Myanmar needs to be pursued in a mid and long-term, an electric power supply plan for the high-speed rail needs to be established considering the high-speed rail's power consumption and the plan for the expansion of electric power generation at the national level.

5.3.1. Ways of Application to Myanmar

• High-speed rails are electrified ones, in principle, and require an enormous power consumption. Thus, national power supply infrastructure must be established for stable power supply.

• Power supply systems can be divided into transmission lines, substations, catenary systems, and electric facilities, and technical matters of each of them have already been mentioned earlier.

5.4. Signaling System

5.4.1. Overview

• This section describes the basic concept of the establishment of signaling systems, the present condition of the signaling systems applied to Korea's high-speed rails, and considerations for the establishment of signaling systems and their composition.

• As signaling systems are evolving rapidly along with advanced-technology development, this section will introduce the latest signaling systems applicable to the high-speed rail in Myanmar in the future and provide ways of establishing them.

5.4.2. Basic Concept

• Signaling systems should be designed by automatizing them by the latest technology so that operations based on the operator's attention or judgment may be minimized, by applying a multi-system composition for major parts, and so as to be fail-safe.

• Signaling systems should be designed so that they can detect any faults caused by natural phenomena and take action such as slow-down or stop of trains and that they can be protected against artificial faults.

- For train operation control systems, signaling systems suitable to the safe operation at a speed of 300 km/h or faster should be applied.

- Also, the optimal signaling systems should be selected by reviewing safety, reliability, constructability, maintainability, economic performance, future development concept, etc.

5.4.3. Railway Signaling Technology Development Status

- Signaling systems have evolved from manual signaling by humans to mechanical signaling to electric signaling to electronic signaling and to telecommunication- based signaling.

- Signaling methods are divided into wayside signaling and cab signaling. Wayside signaling method is that signals are displayed using colored-light signaling devices, and then the train driver sees them, makes a judgment and drives the train as appropriate. It cannot be applied when the train operation speed is higher than 160 km/h. Cab signaling is that signals or speeds required for train operation are displayed in the cab and the train is operated accordingly. This method is mostly applied to the rail lines constructed recently.

- Block methods have evolved from fixed block to distance-to-go block to virtual block and then to moving block.

- As there had been no international standard for signaling systems until recently, there were a lot of difficulties in securing inter-operability with system suppliers' technical specifications, but in the case of Europe, the standard specification of ERTMS/ETCS Levels 1, 2 and 3 was established and has been applied for the railway interfaces between European countries and for direct operations.

- China has established and applied the specification of CTCS Grades 1 to 4 like ETCS, securing the compatibility with ETCS signaling systems.

- Korea's high-speed rails introduced European railway signaling technologies, operating ACT cab signaling systems (TVM-30). As, however, they are products of proprietary suppliers and the inter-operability has not been secured, there have been difficulties in establishing the signaling systems in consideration of train interface, direct operation and track extension.

- Although the railways recently constructed and upgraded in foreign countries have adopted the method of ERTMS/ETCS Level.2 (GSM - R), as telecommunication technology evolves, it is being planned to change the communication method from the existing GSM-R method to the next-generation LTE-R method.

- In the line sections which to be upgraded into a higher speed in Korea, the inter-operability has been secured by applying the cab signaling system of ERTMS/ETCS Level.1 (ATP), and for the next-generation signaling systems applicable to the conventional rails and high-speed rails (300 km/h) newly built, KRTCS-2 (Korea Radio-based Train Control System, LTE-R method) has been developed and is being put to practical use. This is going to be applied.

- To apply ERTMS/ETCS Level.2 (GSM - R) or KRTCS-2 (LTE-R) cab signaling system to the high-speed rail in Myanmar, frequencies dedicated to the rail should be allocated.

5.4.4. Present Condition of Korea's Railway Signaling Systems

Table 151 | Signaling System Application Sections & Present Condition

Category	Sections	Present Condition
Cab Signaling	• HSRs: Gyeongbu, Honam, capital-regional HSRs (dedicated HSR lines)	• Cab signaling by ATC (TVM-430)
	• Lines to be upgraded in speed: Gyeongbu Line 1, Honam line, Jeolla line, Gyeongchun line and Gyeonggang line	• Cab signaling by ERTMS/ETCS Level.1(ATP) (Eurocab)
	• Metropolitan rails in Korea (Bundang line, Ilsan line, Gwacheon line, parts of Suin line, etc.)	• Cab signaling by ATC • There is no ATO function.
	• Urban rails (Incheon airport rail, Seoul lines 5-9, Daegu line 1, Busan line 1, etc.)	• Cab signaling by ATC (ATC/ATO) • Speed step method
	• Urban rails (Incheon 1, Daegu 2, Busan 2, Gwangju 1, Daejeon 1, etc.)	• Cab signaling by ATC (ATP/ATO) • Distance-to-Go method
	• Urban rails (ShinBundang, Incheon 2, Busan 3~4)	• Cab signaling by ATC (ATP/ATO) of CBTC type
Wayside Signaling	• Metropolitan rails (Gyeongin line, Suin line, Jungang line, etc.)	• ABS/ATS operation by 4-phase wayside signaling
	• Arterial rails (Gyeongbu line, Honam line, Jeolla line, Jungang line, etc.)	• ABS/ATS operation by 3&5-phase signaling

1) High-speed Rails (ATC System, TVM)

- ATC systems (TVM-430) are the ones installed along the high-speed rail by Ansaldo STS's technology transfer to Korean companies. The systems are configured so as to be connected with IXL. And their train control method uses AF track circuit devices.

- Signaling systems, which are the equipment for signaling rooms, are composed of ATC system, electronic interlocking devices, safety systems, safety system control boards, integrated maintenance support systems and power supply systems. Wayside systems are made up of ATC systems (AF track circuit devices), various signs, and safety systems (obstacle detectors, tunnel alarm devices, repairers crossing equipment, dragging detectors, climate detectors, track switch heaters, rail temperature detectors, hot-box detectors, trackside earthquake detectors, etc.) and also include the integrated control systems of CTC with the functions of monitoring and control for the safe operation of trains.

2) ERTMS/ETCS Systems

- In the early times, various signaling systems were applied to different line sections. Accordingly, there were the difficulties that trains had to be operated with double sets of onboard equipment mounted, for the signaling systems were inconsistent in the connected sections where the trains operated.

- The European Union devised the standardization of railway signaling systems by having an organization of European train control systems (ERTMS/ETCS) under European Rail Traffic Management Systems (ERTMS) in order to improve international railway operation efficiency.

- ERTMS/ETCS are applicable to all kinds of railway services. The core of such generality can be achieved on the basis of the functional autonomy allocated to the onboard devices. This functional generality includes various functions needed to monitor and enforce the speeds.

- The biggest merit of this concept is that not only the inter-operability between various networks but also between parts of them are possible. In the past, various train control and communication systems were employed, but in some cases, there were no such systems.

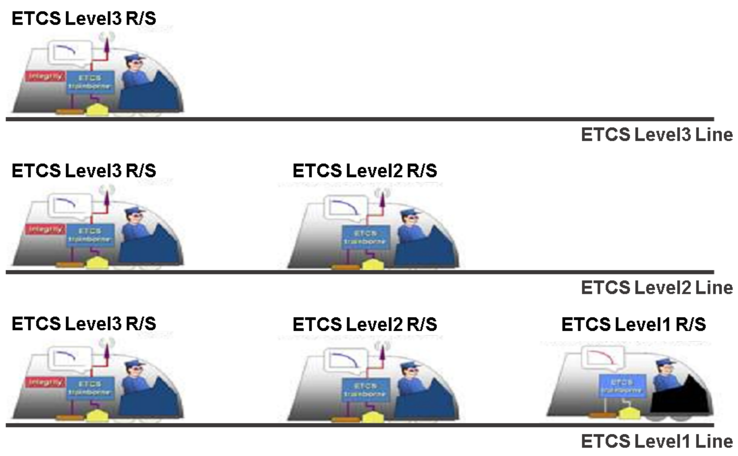
- But ERTMS/ETCS provide the optimized, wide range of the trackside equipment densities, and have the merit of being capable of providing considerable flexibility for the upgrade plan from an old-style system to a new-style system by overlaying the ERTMS/ETCS systems over the existing signaling systems.

Table 152 | Comparison of ERTMS/ETCS Levels

Level	0	1		2	3	STM
Trackside signals	Y	Y		Not needed	Not needed	Y
In-Fill Information	N	N	Balise, loop radio	N	N	N
Transmission	Balise	Balise	Balise, loop, Radio in-fill	Balise, radio	Balise, radio	Balise
Radio network	N	N	Local	Entire	Entire	N
RBC	N	N		Y	Y	N
Train integrity	N	N		N	Y	N
High-performnace block	N	N		Y	Y	N
Moving block	N	N		N	Y	N
Localization	Balise	Balise		Balise	Balise	STM Balise
Fouling point detection	Trackside	Trackside		Trackside	Onboard	Trackside
Type of Balise	Fixed	Fixed & variable		Fixed	Fixed	STM
LEU	N	Y		N*	N*	N
Signaling	Trackside	Trackside		Onboard	Onboard	Trackside
DMI	Speed	Overlay		Cab signaling	Cab signaling	Cab signaling

* Possible to use LEU; e. g., change of levels associated with route setting
Notes: Y: Yes, N: No

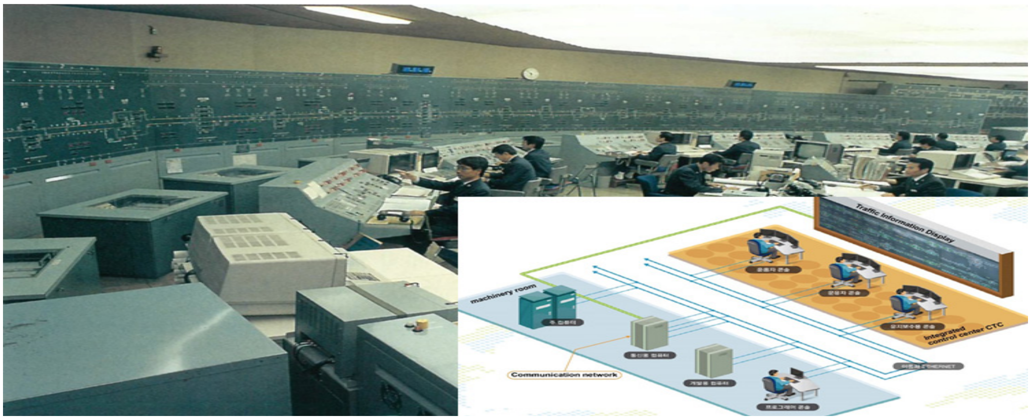
Figure 71 | Compatibility between Levels Applied to ERTMS/ETCS



3) CTC System

• CTC (Centralized Train Control) systems, which control signals and train operations remotely from one place, process train operation commands rapidly and accurately by monitoring the operating condition of trains, in order to improve the track usage efficiency and rationalize the railway management by computerizing train operation management systems.

Figure 72 | Computerized Train Operation Management System



Source: KRNA, http://www.kr.or.kr/sub/info.do?m=06120404

4) IXL

- The IXL system in the station yard is the key signaling system that converts the condition of field signaling security devices such as signals, electric track switches and track circuits into logic and provides safe route conditions for operating trains. It should be designed to be fail-safe (even if the signaling device fails, the other redundant one takes over.). By applying electronic interlocking devices with a self-diagnostic function, it is so configured that it can recover immediately in the event of a failure, by displaying the condition in detail on the maintenance information system.

5.4.5. Signaling System Establishment Method

- Signaling systems should be selected by reviewing safety, reliability, expandability and possibility to upgrade, economic performance, convenience of maintenance, marketing potential, future orientation, applicability of international standard specifications, and inter-operability of mixed trains.

- In South Korea, colored-light signals were used before the introduction of high-speed rails; when signals were displayed, the driver saw them make judgment, which is called 'wayside signaling.' But this method cannot be applied when the speed is faster than 160 km/h.

- Thus, high-speed rails are using cab signaling method, in which signals or speeds needed for train operation are displayed in the cab for the driving of trains.

- Until recently, there had been a lot of difficulties in interoperability because there was no international standard and instead, system suppliers' technical specifications were employed. But in Europe, the standard specifications of ERTMS/ETCS Levels 1, 2, and 3 were established and have been applied for the interface between the railways in European countries and for direct operation.

- Korea's high-speed rails introduced European railway signaling technology and have operated ATC cab signaling systems (TVM-430). As, however, there was no interoperability between the companies because the products were from proprietary suppliers, there were difficulties in establishing signaling systems in consideration of line extension, direct operation and train interfaces.

- Internationally, the railways recently built and upgraded are applying ERTMS/ ETCS Level.

2 (GSM - R), but with the development of communication technology, the communication method is being planned to be changed from the existing GSM-R method to the next-generation LTE-R method.

- In Korea's higher-speed lines (faster than 150 km/h), the interoperability has been secured by applying ERTMS/ETCS Level.1 (ATP) cab signaling systems, and as the next-generation signaling systems applicable to the conventional rails and high-speed rails (300 km/h or faster) newly built, KRTCS-2 (Korea Radio-based Train Control System, LTE-R method) is planned to be developed and is put to practical use.

- In order to apply ERTMS/ETCS Level.2 (GSM - R) or KRTCS-2 (LTE-R) cab signaling systems to the high-speed rail in Myanmar, frequencies dedicated to the railway should be allocated.

- As signaling systems are evolving fast along with the development of state-of-the-art technologies, the latest applicable signaling system should be applied when planning the high-speed rail in Myanmar.

- To enhance the safe operation and punctuality of trains, CTC (centralized traffic control) is needed.

- In South Korea, national budgets were spent to establish a railway control center and CTC systems, and all the high-speed, conventional and metropolitan rails are being controlled from one place.

- CTC systems, which control signals and train operation remotely from one place, process train operation commands fast and accurately by supervising the train operation status. By doing so, they improve the track usage efficiency and can rationalize railway management by computerizing the train operation management system.

- In Myanmar, a control center is being operated for each section of the route, but mostly, manual or semi-automatic systems are being operated, resulting in very low safety, punctuality and efficiency. Thus, it is deemed necessary to carry out an upgrade project in connection with the signaling systems as soon as possible.

- For a high-speed rail, safety is of top priority, and the CTC system must be established in a stable way by being connected with signaling systems, IXL, communication systems, etc.

- Through this, train operation commands can be processed fast and accurately by monitoring all the train operation conditions from one place; the track usage efficiency can be improved; and by computerizing the train operation management system, the data can be utilized for railway management usefully.

5.5. Telecommunication Systems

5.5.1. Overview

- For the fast, accurate and safe operation of trains and for the successful establishment of operating systems, telecommunication systems for train driving and operation, those for passenger services, and those for maintenance and disaster prevention should be set up.

5.5.2. Basic Concept

- For the safe operation of the HSR and convenient and prompt train services for the passengers, a telecommunication system should be set up to transmit various forms of information (voice, data, image, etc.) in a fast and accurate way between organizations.

- The control center should be capable of monitoring and controlling all the facilities for train operation, stations and passengers, and when extending the line, it should be easy to make linkage and extension.

- For the telecommunication systems for the HSR in Myanmar, the telecommunication system applied and being operated in the HSRs in South Korea is suggested basically.

- Telecommunication systems are advanced technologies that are evolving rapidly, and when planning for the HSR in Myanmar, the latest system should be applied.

5.5.3. Development Direction of Rail Telecommunication

- Of the systems applied to the rail telecommunication, major facilities are as follows:

1) Transmission facilities

- Fiber-optic facilities are adopted. Thus, fiber-optic cables and fiber-optic terminals should be set up. For all the terminals, IP method has been applied.

2) Video transmission facilities

- High-resolution cameras are applied so that crystal clear images of the train operation in all stations can be transmitted to the stations and the control center on a real-time basis.

3) Train radio system

- It is being changed from the existing VHF and TRS method into LTE-R method.

4) Train destination information system

- It is being changed from Dot LED, LCD, and PDF methods into LED method, which requires a low level of power consumption.

5) Automatic fare collection system (ticketing) for high-speed rails

- It has been changed from the functions of ticketing and ticket inspection at the gates into the functions of in-vehicle ticket inspection using wireless terminals.

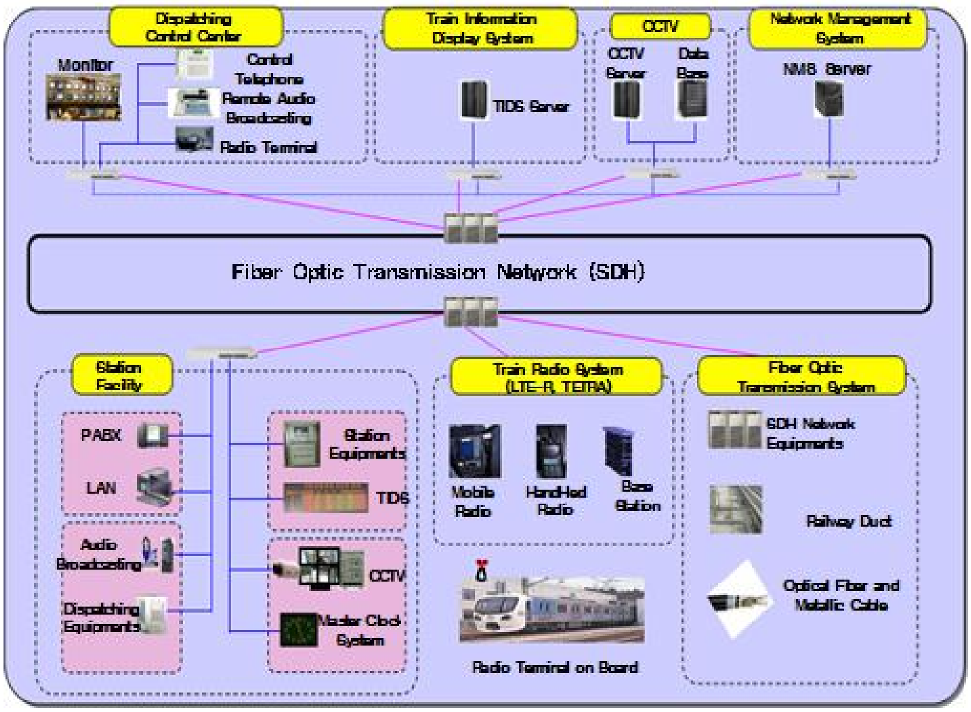
6) Trackside telephones

- It is being developed into the ones with functions of collecting and transmitting information to related organizations by accommodating various sensors and terminals for control.

5.5.4. Korea's Railway Telecommunication System Setup Status

- Korea's railway telecommunication is a system to transmit various kinds of information (voice, image, data) generated during rail management and operation to various departments promptly and accurately. Considering various kinds of information and its usage, which are on the increase, the integrated telecommunication network to be introduced in the future and transmission quality, the optimal telecommunication network has been established.

Figure 73 | Korea's Railway Telecommunication System Configuration



• For the transmission line, flame-retarding, long-wave fiber-optic cables of single mode that are used for high-speed, large-capacity transmissions are installed. Their type and configuration are planned to be a double ring network for redundant telecommunication networks.

1) Telecommunication systems for operation & management

• The telecommunication system for operation and management is the one for the performance of railway operation and management. It employs IP-type exchange systems so that the information required or the data generated from each department can be exchanged from time to time and has been configured so that it can accommodate each station, R/S depot and control center.

2) Telecommunication systems for train-driving management

- The telecommunication systems for train-driving management are directly related to the train driving and is made up of train radio systems for the calls between the commander's office and the train, between the train operation staff and the train, and between the maintenance personnel and the operating center, commander's telephone system for the calls between the commander's office, each station and the branch office, and CCTV systems for the supervision of passengers on the platforms.

3) Telecommunication systems for passenger services

- The telecommunication systems for passenger services have been composed of automatic announcement facilities, train destination information indicators, integrated telecommunication networks and electric clock systems so as to ensure comfortable rail services by providing the information related to train operation for the passengers in the concourse and platforms in each station.

4) Telecommunication systems for facilities maintenance

- The telecommunication systems for facilities maintenance have been made up of trackside telephones and portable radio-phones so that emergency calls can be made during the works in tunnels or along the track.

5) Telecommunication systems for rolling stock depots

- The telecommunication system for the rolling stock depot has been composed of the following facilities in order to ensure the safe operation of the trains going in and out of the depot, successful maintenance of various operation and management facilities and the prompt and accurate exchange of various kinds of information among operating departments:

- Train radio system
- Commander's telephone system
- Talk-back facilities
- In-depot exchange systems
- PA system
- Satellite broadcasting receiving system
- CCTV system
- Power supply system

6) Power supply system

- The power supply system has been configured to be an un-interruptable one that functions even in the event of power failure for the stable power supply to various telecommunication equipment and terminals.

7) AFC (Automatic Fare Collection) system plan

- Automatic Fare Collection System (AFC) has been set up that is convenient to use and has been improved in its performance to sell and collect tickets and process various accounting data.

5.5.5. Ways of Establishing Telecommunication Systems in Myanmar

- To transmit various kinds of information required for the train driving and operation (voice, image, and data) promptly and accurately and considering the easiness to operate and maintain, economic performance and expandability, the telecommunication system for Myanmar is suggested to be the one that considers the future development of telecommunication based on the system established and being operated in South Korea.

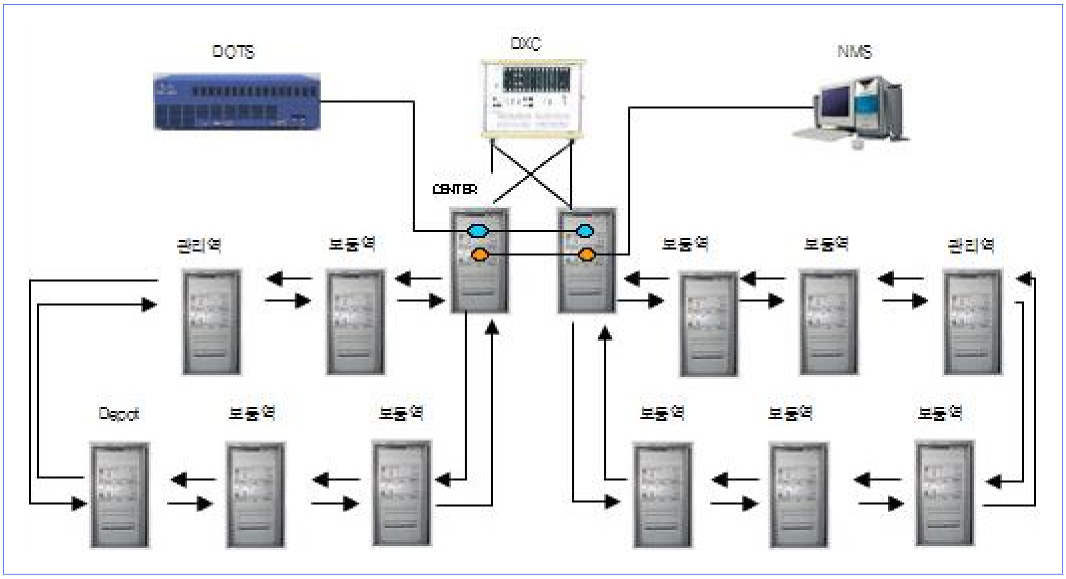
1)Line facilities

- The main and auxiliary transmission lines should be installed with fiber-optic cables that are not affected by induction, are light-weight and are possible to provide super-high speed broad-band services with few transmission losses.

2) Transmission facilities

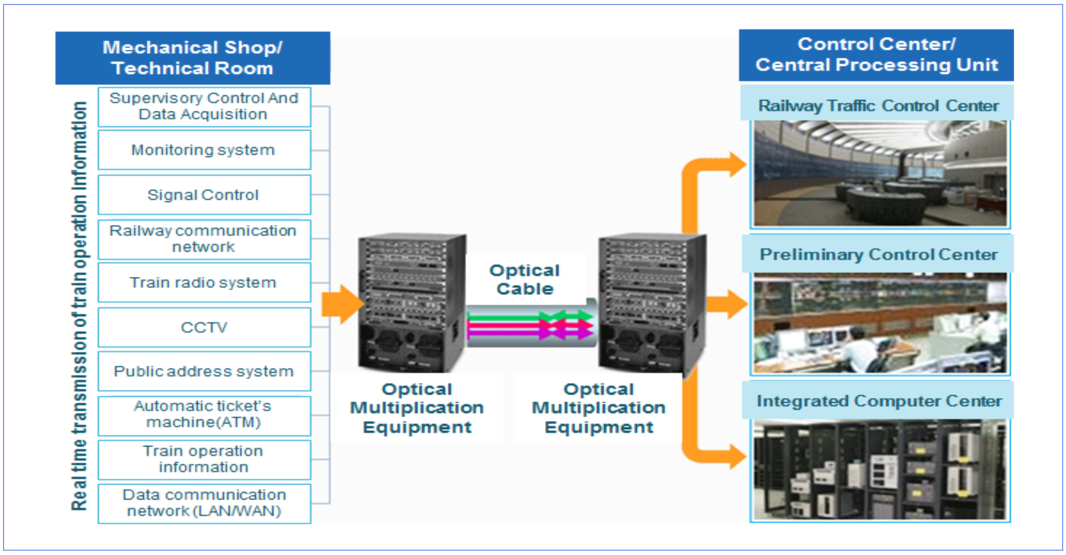
- To transmit various kinds of information in large quantities such as voice, image and data required for the train driving and operation and considering the future development trend of digital technology and Korean and foreign standardization methods, digital multiple transmission (STM-1, STM-16) and DWDM fiber-optic transmission facilities are installed so that their economic performance and expandability can be ensured.

Figure 74 | Configuration Diagram of a Transmission Network



3) Train radio system

Figure 75 | Configuration Diagram of TRS



Source: KRNA, http://www.kr.or.kr/sub/info.do?m-06100204

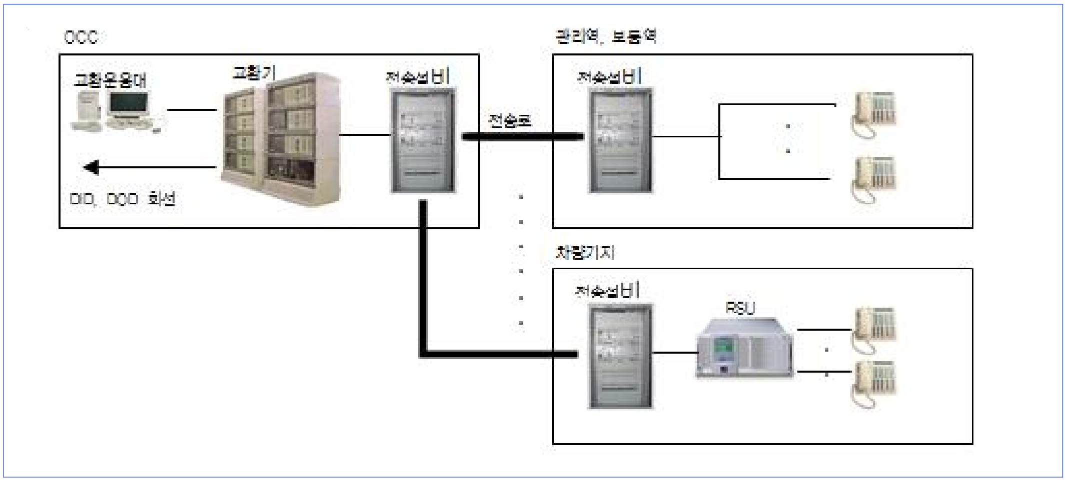
• The train radio system should be configured so that calls to maintenance personnel and related departments can be made using portable radio phones and that wireless calls to the operating train driver can be made from the control center or the operation office regarding the safe operation of trains.

• By TRS (800Mhz) method or LTE-R method, the system should be configured so that calls from the commander's office, main line, station and the rolling stock depot to the commander, train crew, station crew and maintenance personnel and vice versa can be made.

4) Electronic exchange systems

• IP switching networks should be set up so that various voice calls generated during train operation can be processed smoothly.

Figure 76 | Configuration Diagram of an Electronic Exchange System



5) Video transmission system

• For the video transmission system, cameras should be installed in the platforms and lobbies in each station. The images collected are supervised from the station office in order to ensure safe operation of trains and efficient work performance.

• The DVR employed should be as follows: by making the manipulation more convenient, the recorded data can be easily played back, and the capacity of the storing media is large, and the DVR can be used permanently.

6) Telephone system

- For the telephone system, optical transmission systems should accommodate the subscribers and IP electronic exchanges in the stations and rolling stock depots so that necessary information can be delivered between the telephone subscribers for the train operation and maintenance.

7) Commander's telephone system

- The commander's telephone system is a system for train operation and maintenance and should be configured so that information can be exchanged promptly and accurately by using individual, group and general calling methods between each commander and the site.

8) Trackside telephone system

- The trackside telephone systems accommodated by the IP exchange systems along the trackside and in tunnels are used for prompt calls to related organizations during structural maintenance and in an emergency.

9) PA (Public Address) system

- PA systems provide train operation information for train users and crew in the lobbies and platforms. They can make individual or general announcements, and even when some AMPs fail, the systems should be capable of making announcements continuously. This system is called an incremental type system.

10) Destination indicators

- Destination indicators are configured so that the information on train location is received on a real-time basis and arrival and destinations are displayed by each station's LSE on the indicators installed over the ticket windows and platforms along the up and down lines.

11) Electric clock systems

- Electric clock systems are configured so as to provide consistent and accurate time information for each station and rolling stock depot and provide efficient operation management and services for passengers by doing so.

12) Power supply system

- The power supply system should be configured so that stable power supply can be made for various telecommunication equipment and terminals in telecommunication equipment rooms, and preparations can be made for power failure or power supply abnormalities. Constant-voltage and constant-frequency power must be supplied uninterruptedly.

6. Rolling Stock Depots

6.1. R/S Depot Overview & Basic Concept

6.1.1. Overview

- R/S depots, which are facilities to repair, clean, inspect and store rolling stock, are crucial for the safe operation of trains. Thus, the location of a R/S depot should be selected considering the efficiency and economics of train operation, and it should have a site large enough to contain facilities that suit the size of the fleet.

- The size of the site is set by the maintenance scale and the number of trainsets of the final target year, and should consider the dead-heading distance by the distance to the origin and destination stations, national land utilization plan, local government's urban plan, development plans and applicable laws and regulations.

6.1.2. Basic Concept

- The depot should be situated as near to the origin and destination stations as possible for enhanced operation efficiency.

- The site should have the area of a rectangular shape required for the arrangement of rolling stock depot facilities in a smooth and level terrain.

- The site should be easy to expand in the future and to accommodate shunting movements by trains.

- The location should be in line with various upper-level plans and cause little damage to the surroundings.

- The land should be easy to buy and the project cost including compensation cost should be low.

- The site should be easy to supply utilities such as water supply, sewerage, power supply, and gases.

- The works of rolling stock storage and maintenance should be designed to be efficiently interfaced.

- The facilities should be laid out in a reasonable way; their operation efficiency should be maximized; and they should be environment-friendly.

- The standard maintenance method and system for the operating rolling stock should be investigated closely and be incorporated.

6.1.3. Layout Plan for the Facilities in the R/S Depot

- The track layout plan should be established taking into account the movements of the stored and released vehicles, the location and installation conditions of maintenance shops, automatic routine inspection shops, wheel lathes, and automatic car-body cleaners, which are directly related to the track layout.

- The waste water generated from the automatic car-body cleaners should be planned to be circulated and utilized in its entire amount, and the cleaners should be laid out on the track coming into the storage house by considering the efficiency of the depot.

- The integrated administration building should be situated at a location that is easily accessible by workers and visitors.

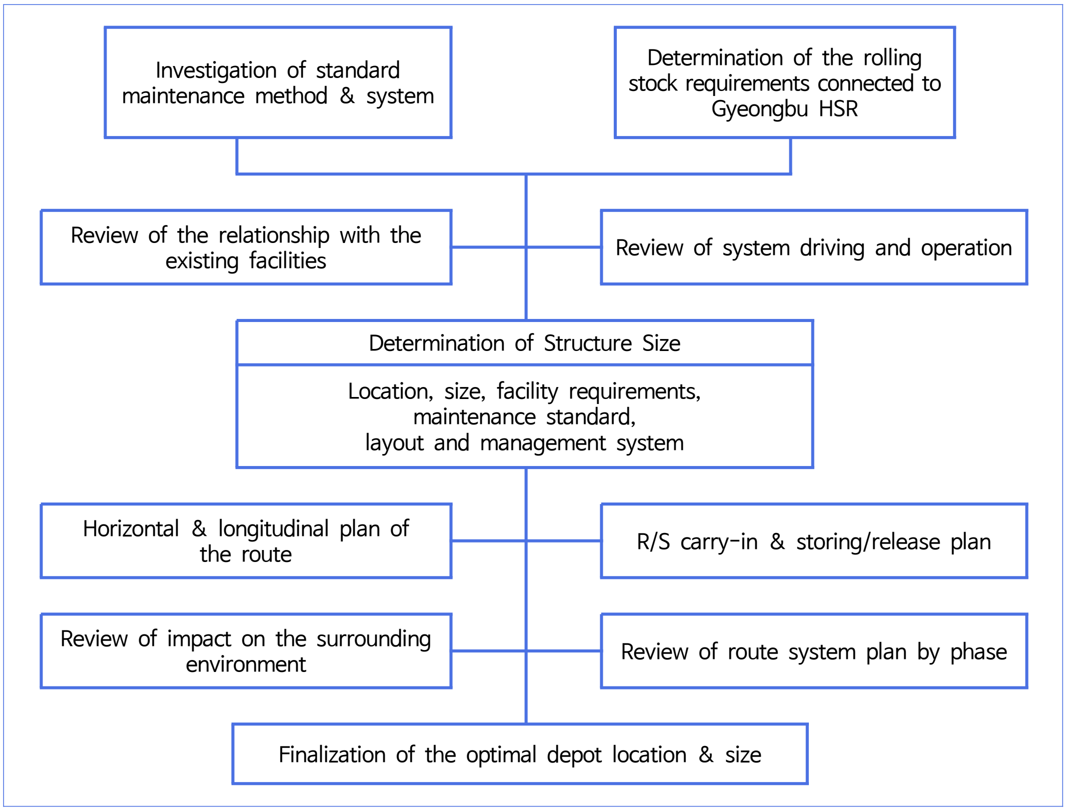
- The substation and electric rooms should be located at the center of the electricity supply load and in the rolling stock depot in order to improve the efficiency of power supply.

- The wheel lathe should be designed so that one trainset can be stored before and after it each.

- The sewage treatment plant should be laid out so as to be adjacent to the automatic car-body cleaner and the maintenance shop, which are the main sources of sewage.

6.1.4. R/S Depot Work Flowchart

Figure 77 | R/S Depot Planned-Work Flowchart



6.2. Maintenance System for the R/S Depot

- The maintenance system should be based on preventive maintenance, and be designed considering the persisting period of each component that serves as a crucial factor for the rolling stock conditions or maintenance conditions, the characteristics of work flows, maintenance facilities, the effect of investment, and maintenance equipment and its operation effect.

• Considering the features of high-speed rail vehicles, the Detailed Rules of Rolling Stock Maintenance established by Korea Railroad Corporation (KORAIL) are applied as the standard.

Table 153 | Detailed Rules of Rolling Stock Maintenance

Maintenance Activity	Standard (Running distance)	Cycle	Remarks
Examination Service, ES	5,000㎞	-	Periodic maintenance
Comfort Examination, CE	20,000㎞	14 days	
Running Gear Inspection, RGI	20,000㎞	14 days	
Systematic Works on Trainset, SWT	50,000~55,000㎞	-	
Season-SWT, S-SWT	Before and during summer & winter	-	
Period-SWT, P-SWT	When each cycle comes	-	
Limited Inspection, LI	150,000~165,000㎞	4 mon.	
General Inspection, GI	300,000~330,000㎞	8 mon.	
Full General Inspection, FGI	600,000~660,000㎞	16 mon.	
Replace Between Overhaul, RBO	At the time of replacement for the ECO of part assemblies	-	
Equipment Component Overhaul, ECO	At the time of overhaul of part assemblies	-	
Comport Esthetic Operation, CEO	When necessary	-	
Half Life Operation, HLO	Before and after a 15-year operation (max. ±20%)	-	
Temporary Inspection, T	From time to time	-	Special maintenance
Special Inspection	From time to time	-	
Wheel Turning, WC	When necessary	-	

Source: KRNA, 'Detailed Rules on Rolling Stock Maintenance,' 2014

6.3. Case Studies on Major Countries' R/S Depot Operation

• For high-speed rails, KTX in South Korea, TGV in France, ICE in Germany, AVE in Spain, and Shinkansen in Japan have been operated with R/S depots and maintenance shops. Their R/S depot operation status is as shown in the following table:

Table 154 | Currently Operated R/S Depots in Countries

South Korea (KTX)	• Seoul (Goyang) Depot / Busan Depot / Gwangju Depot
France (TGV)	• Conflans Depot / Villeneuve Depot / Chatillon Depot / • Landy Depot / Hellemes Depot / Bischheim Depot
Germany (ICE)	• Hamburg Depot / Munchen Depot / • Nurenberg Workshop
Spain (AVE)	• Cerro Negro Depot / La Sagra Workshop
Japan (Shinkansen)	• Tokyo Depot / Nigata Depot / Hakada Depot / Sendai Workshop

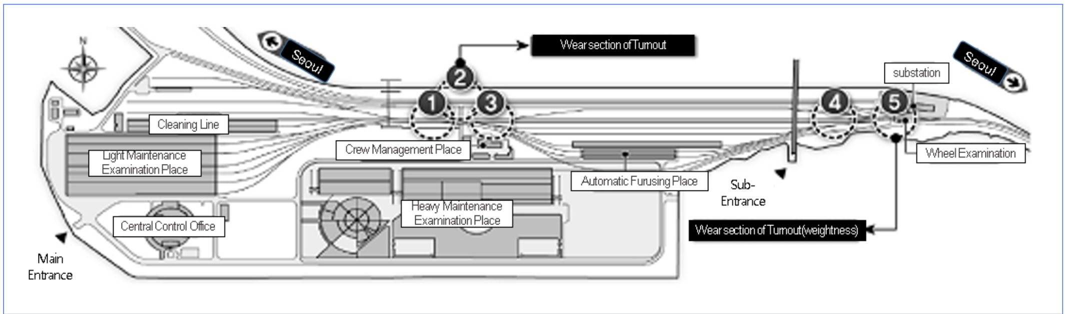
- South Korea (KTX)'s high-speed rail R/S depots have been operated in Seoul, Busan and Gwangju, and of them, the representative Seoul Depot can be described as follows:

- Seoul R/S Depot, which serves Gyeongbu, Honam and capital-region HSRs, has operated heavy- and light-maintenance facilities.

- The area of its site is 1,340,787㎡; the architectural area is 117,060㎡; its maintenance scales are 44 trainsets in Step 1 and 56 in Step 2; and its storage capacities are 24 trainsets in Step 1 and 56 in Step 2.

- The present facility layout is as illustrated below.

Figure 78 | Present Facility Layout in Seoul R/S Depot



Source: KRNA, http://www.kr.or.kr/sub/info.do?m-05020205

6.4. Review of the HSR R/S Depot in Myanmar

- For the Yangon~Mandalay HSR construction, it is advisable to locate the R/S depot near the terminal of the route when considering the track length and South Korea's operation experience, but there are difficulties in selecting the locations of Yangon and Mandalay Stations near it, for they are located in downtowns.

• For the location of Yangon R/S Depot, Myanma Railways(MR) is considering Ywathagyi, which is planned to be the site for the R/S depot for the Yangon~Mandalay rail upgrade project.

• In the case of Mandalay, it may vary with the location of the station, but if the location of the station is planned to be in the downtown, it is deemed proper to locate it at the start point of Myitnge Station, and if the location of the station is planned to be at the outskirts, at the end point of the station.

• Based on 2040, the study team has estimated about 36 trainsets to be required for Yangon~Mandalay (a 10-car trainset; refer to the train operation plan). Although the area of the rolling stock depot and the area of buildings vary greatly with the depot layout, groups of storage tracks and land shape, when considering South Korea's maintenance capacities similar to the Gwangju R/S Depot for Honam HSR (maintenance capacity: 37 trainsets based on a 10-car trainset), the area of the R/S depot is estimated at about 450,000 ㎡ with a building area of 44,000 ㎡.

• Major facilities to be laid out are an integrated administration building, a maintenance building, a building for operation branch office and crew management office, an integrated substation and ten ancillary buildings, and tracks for the R/S depot including maintenance, storage, engine running and draw-out tracks.

7. High-speed Rail Rolling Stock

7.1. verview of HSR R/S

• In the construction of a high-speed rail, the selection of rolling stock is more important than anything else and should be made by reviewing the features of the route, train operation, transport demand, etc.

• When introducing rolling stock, there must be the option of rolling stock technology transfer so that Myanmar can manufacture the rolling stock independently through technological development in the future.

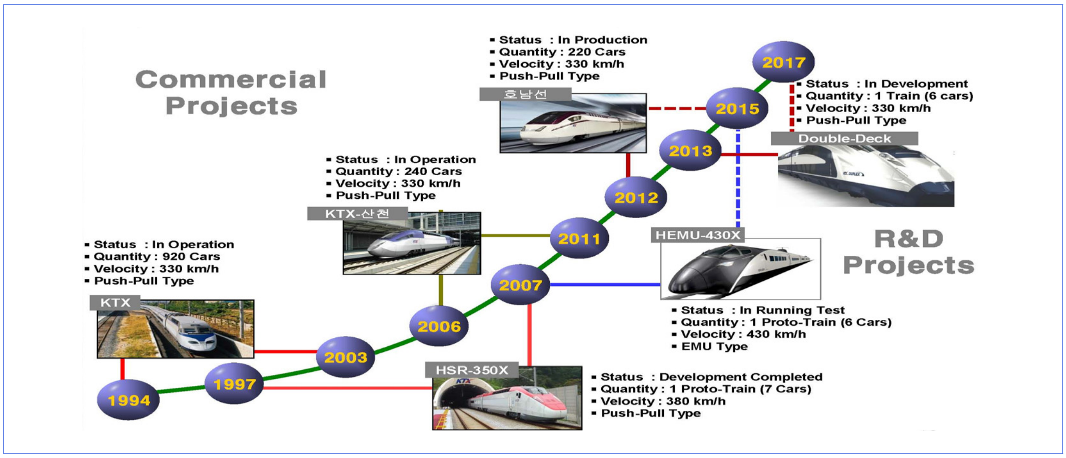
• In the case of South Korea, the independent production of rolling stock was made through the option of technology transfer at the time of introducing the TGV fleet from France and through independent technological development.

• The countries that can manufacture high-speed rail vehicles independently include France, Germany, Japan, and China in addition to South Korea. The speeds of the vehicles currently being operated around the world are mostly 200 km/h to 300 km/h, but recently, countries are competing one another in developing super-high speed vehicles that can run faster than 400 km/h.

7.2. B. South Korea's High-speed Rail Fleet

• The present condition of South Korea's introduction and development of high-speed rail fleet is as follows:

Figure 79 | Present Condition of South Korea' s Introduction & Development of HS Trains



Courtesy: Mr. Hyung-Woo Lee of Korea National University of Transportation, 2016
Source: KRRI, 'Ways of Korean HSRs' Entering the Offshore Market,' 2016

• The high-speed trains operated and developed in South Korea are as shown in Table IV-32 and it is deemed possible to apply them to the HSR in Myanmar:

• KTX-1 is a train imported from Alstom in France or assembled in South Korea in accordance with the terms and conditions of the contract, and the other trains were developed independently in South Korea.

• The trains introduced at the initial stage or developed in South Korea employed centralized power method, but recently, distributed power method was chiefly developed. The distributed power system is advantageous to accelerate and decelerate and is suitable for super-high speed operation.

Table 155 | South Korea's High-speed Trains Applicable to the HSR in Myanmar

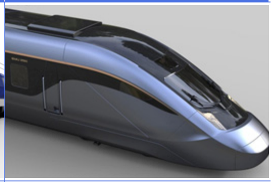
Category			KTX-1 (Imported from Alstom, Assembled in South Korea)	KTX-Sancheon (Under operation)	HEMU 320 (Completely developed)
					
General	Powering		Centralized	Centralized	Distributed
	Train consist		20-car, single consist (2 power cars, 2 motorized passenger cars 2, 16 passenger cars)	10-car, possible to be double-headed (2 power cars, 8 passenger cars)	8-car, possible to be double-headed (6 power cars, 2 control cars)
	Max. operating speed		300km/h	300km/h	320km/h
	Max. design speed		330km/h	330km/h	352km/h
	Trolley voltage		25KVAC	25KVAC	25KVAC
	Max. tractive power		385kN (Based on a 20-car train)	210kN (Based on a 10-car train)	303kN (Based on an 8-car train)
	Max. acceleration		0.47m/s2 to 60km/h	0.45m/s2 to 60km/h	0.56m/s2 to 100km/h
	Axial load		17 tons or less	17 tons or less	15 tons or less
	Train length		20-car: 387m	10-car: 201m	8-car: 199.1m
	Width of a car		Power car : 2,814 mm Trailer Car : 2,904 mm	2,814 mm 2,970 mm	3,150 mm
	Seating capacities		20-car: 935 seats (Deluxe room (4): 127 seats, Standard room: 808 seats)	10-car: 410 seats (Deluxe room: 33 seats, Standard room: 377 seats)	8-car: 515 seats (Deluxe room: 46 seats, Standard room: 469 seats)
Car Body	Material of car body	Power car	Steel & composite material	Steel & composite material	Steel & composite material
		Motorized passenger car	Steel	-	Aluminum
		Passenger car	Steel	Aluminum	-
Traction Motor	Type		Synchronous motor (3-phase 6-pole)	Induction motor (3-phase 4-pole)	Induction motor (3-phase 4-pole)
	Capacity		1130kW x 12	1100kW x 8	380kW x 24

Table 156 | South Korea's High-speed Trains Applicable to the HSR in Myanmar

Category			HEMU 430x (Completely developed)	HSR 350x (Completely developed)	Double-deck HS Train (Under development)
					
General	Powering		Distributed	Centralized	Under review
	Train consist		8-car (6 power cars, 2 control cars)	7-car (2 power cars, 2 passenger cars, 3 test cars)	Under review
	Max. operating speed		370km/h	350km/h	300km/h
	Max. design speed		430km/h	385km/h	330km/h
	Trolley voltage		25KVAC	25KVAC	25KVAC
	Max. tractive power		240kN (Based on an 8-car train)	400kN (Based on a 20-car train)	Under review
	Max. acceleration		0.5m/s2 to 160km/h	0.49m/s2 to 100km/h	
	Axial load		13 tons or less	17 tons or less	
	Train length		8-car: 197.6m	7-car: 148.2m	8-car: 202m
	Width of a car		3,150mm	2,814mm 2,970mm	2,970mm
	Seating capacities		6-car: 362 seats (45 seats on average)	2-car: 82 seats (Deluxe room: 26 seats, Standard room: 56 seats)	8-car: 616 seats
Car Body	Car Body Material	Power car	Steel & composite material	Steel & composite material	Steel & composite material
		Motorized passenger car	Aluminum	-	-
		Passenger car	-	Aluminum	Aluminum
Traction Motor	Type		Induction motor (3-phase 4-pole) Permanent magnet motor (3-phase 4-pole)	Induction motor (3-phase 4-pole)	Under review
	Capacity		410kW x 24	1100kW x 8	

Note) HEMU: H, which denotes high-speed, is added to EMU (Electric Multiple Unit).
Sources: 1) KRNA (http://www.kr.or.kr/sub/info.do?m-06100203)
2) Hyundai ROTEM (https://www.hyundai-rotem.co.kr/rotem.asp).

7.3. Major Countries' High-speed Rails

7.3.1. Japan

- Operated trains at 250km/h for the first time in the world in 1963.
- Employed a distributed powering system beginning from the initial stage of development.
- Has developed about fifteen kinds of high-speed vehicles since the opening of Shinkansen in 1964.
  - 0, 100, 300, 400, 500, 700, N700 and 800 series (200km/h~300km/h)
- Its total length of high-speed rails is 2,452km (as of 2011).

- FASTECH 360: Max. design speed 405km/h / efSET: Max. operating speed 350km/h

Figure 80 | Japan's High-speed Trains

Source: Wikipedia, 'https://ko.wikipedia.org/wiki'

7.3.2. France

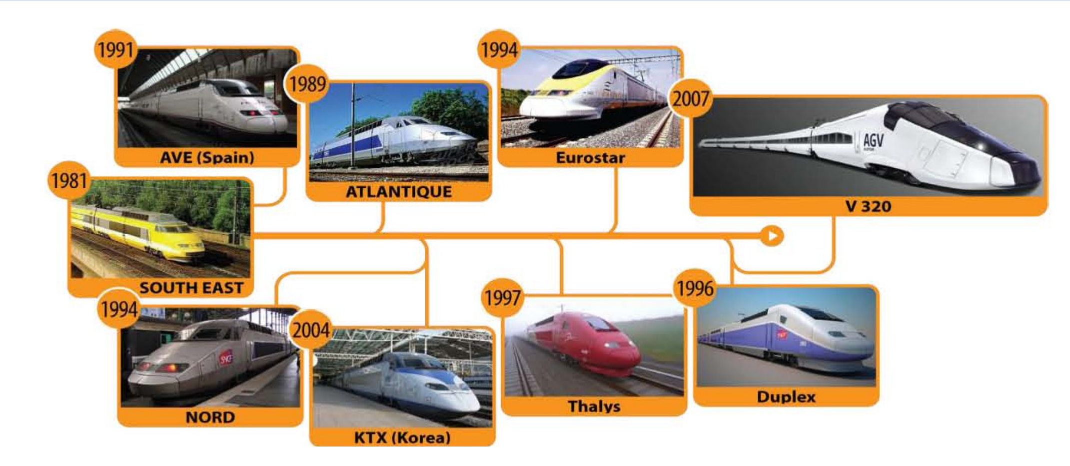
- First generation: Operated a high-speed rail between Paris and Lion (for the first time in Europe, 1981) with a commercial speed of 260km/h.

• Second generation: TGV-Atlantique with a commercial speed of 300km/h

• Third generation: TGV-Duplex, double-deck passenger cars with a commercial speed of 300km/h

• AGV: Developed by Alstom with a maximum speed of 360km/h and a commercial speed of 320km/h.

Figure 81 | France's High-speed Trains



Source: Wikipedia, 'https://ko.wikipedia.org/wiki'

7.3.3. Germany

• ICE Experimental: Made a 5-car train consist in 1988 with a max. speed of 406.9km/h.

• ICE1: Developed as a freight train with a max. operating speed of 250 km/h in 1991.

• ICE2: Developed with a max. operating speed of 280km/h in 1996.

• ICE3 : Developed with a max. operating speed of 300km/h in 2001; distributed power type; can be composed of 8 cars to 16 cars.

• ICE3 Velaro E: Developed with a max. speed of 403.7km/h and an operating speed of 350km/h for the route between Madrid and Barcelona in 2006.

Figure 82 | Germany's High-speed Trains

Source: Wikipedia, 'https://ko.wikipedia.org/wiki'

7.3.4. China

- In the early days, it imported from Germany and Japan and produced the vehicles, and today, it is manufacturing them independently due to the technology transferred.

- CRH 1 (China Railway High-speed) 1: Regina (Bombardier), 200km/h (2006)
- CRH 5: New Pendoline (Alstom): 250km/h (2007)
- CRH 2-Sifang: E2 (Kawasaki): 300km/h (2007)
- CRH 3-Tangshan: Velaro (Siemens): 350km/h (2008)
- CRH 380: Design speed 380km/h, operating speed 350km/h

Figure 83 | China's High-speed Trains

Source: Wikipedia, 'https://ko.wikipedia.org/wiki'

7.4. Ways of Introducing High-speed Trains to Myanmar

• The introduction of high-speed rails to South Korea was made through competitive bidding among three countries—France, Germany and Japan. The evaluation items for bidding included the performance and quality of vehicles, financial conditions, technology transfer, localization and operation experience. Finally, Alstom in France was chosen.

• According to the terms and conditions of the contract, the first twelve trains out of the forty-six (920 cars), introduced to South Korea for the first time, were manufactured in France and assembled in South Korea, and the remaining thirty-four were manufactured and assembled in South Korea.

• On top of that, in accordance with the terms and conditions of technology transfer related to rolling stock, the technical data needed for the manufacturing of rolling stock were provided, and technical training and assistance for 2000 technical professionals were carried out.

• Apart from that, the Korean Government carried out a high-speed rail technology development project, which was one of the advanced-technology development projects (G7), from December 1996 to October 2002, involving 4,934 researchers from 129 organizations (companies, research institutes, universities, etc.) to develop Korean-style high-speed rail systems and secure core technology by investing a total of 210.1 billion KRW.

• Even after that, technology development projects were carried out continuously, producing KTXⅡ with Korea's independent technology in 2006 and completing the development of HSR-350x, HEMU-320x, and HEMU-430x, with double-deck high-speed vehicles facing a trial operation.

* HEMU: Dubbed by adding 'H,' which means 'high-speed,' to 'EMU (Electric Multiple Unit).'

• South Korea went through the process of introducing high-speed vehicles from a foreign country to independent technology development and to export of the vehicles (independence of technology).

• South Korea is the only nation in the world that has experienced the improvement of problems in the process of rolling stock introduction, overcoming of challenges in the independent technology development and competition with advanced countries through technological independence.

• Therefore, if Myanmar intends to introduce high-speed vehicles and technology, we believe that South Korea will surely be their best partner.

8. Safety Facilities for a HSR

• For a high-speed rail, the safe operation of trains is pursued by detecting any detrimental factors to it such as natural disasters and the occurrence of obstacles in advance, making the train running at a high speed stop or slow down. Also, various safety facilities are installed and operated to ensure the safety of the workers on the high-speed tracks. Thus, these aspects need to be taken into account when constructing a high-speed rail in Myanmar.

• Safety facilities can be divided into the ones for train operation and the ones for the protection of workers.

• Train operation safety facilities include hot-box detectors, intrusion detectors, dragging detectors, rail temperature detectors, weather detectors, earthquake monitors, remote supervision devices, and track switch heaters.
• The safety facilities for the protection of workers include tunnel alarm devices, speed limit panels, station yard protection switches, block section protection switches and maintenance personnel crossing equipment.

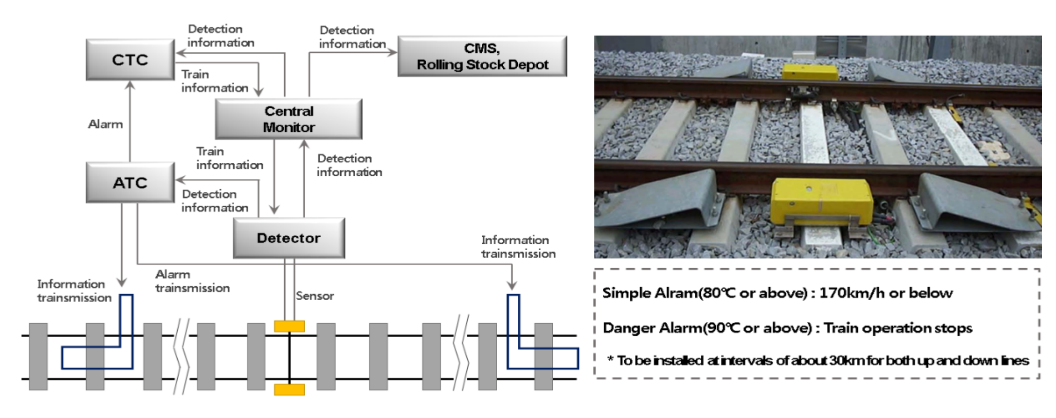
• The functions of safety facilities being operated in South Korea are as follows:

8.1. Hot Box Detectors

• Hot box detectors detect the temperature of the high-speed trains running on the track and transmit alarms to the operation commander or the driver.

• Hot box detectors are installed at intervals of about 30 km.

Figure 84 | Overview of Hot Box Detectors



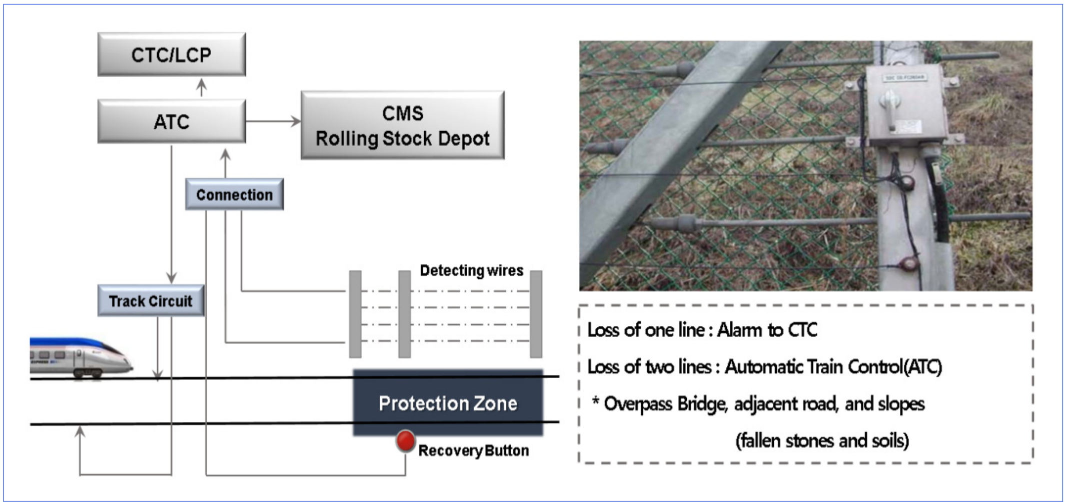
Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.2. Intrusion Detectors

- Intrusion detectors detect obstacles such as automobiles, stones and soils that fell on the track, stop the train automatically, and transmit the contents of alarm to the operation commander.

- Intrusion detectors are installed on over-bridges, adjacent roads and slopes (fallen stones and soils).

Figure 85 | Overview of Intrusion Detectors



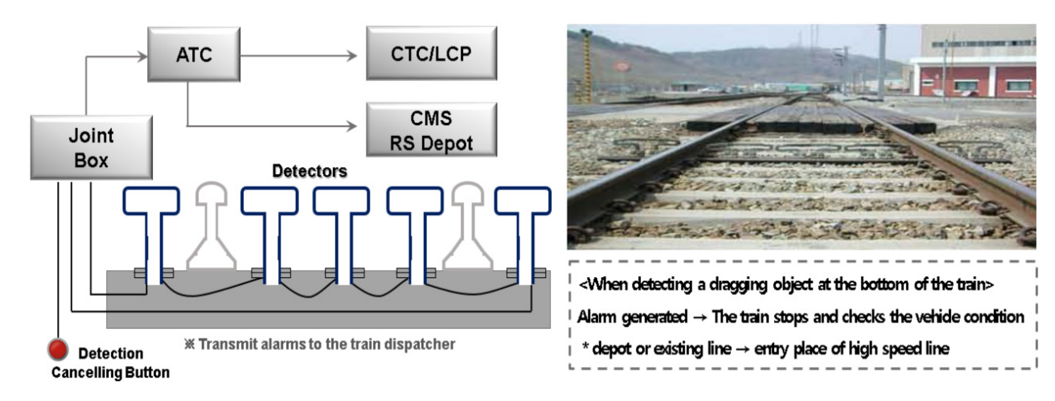
Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.3. Dragging Detectors

- Dragging detectors detect any dragging objects such as parts on the bottom of the train that enters a high-speed line and transmit alarms to the operation commander.

- When detecting any dragging object on the bottom of the train, an alarming sound is generated, and after the train stops, the condition of the vehicles is checked.

Figure 86 | Overview of Dragging Detectors



Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

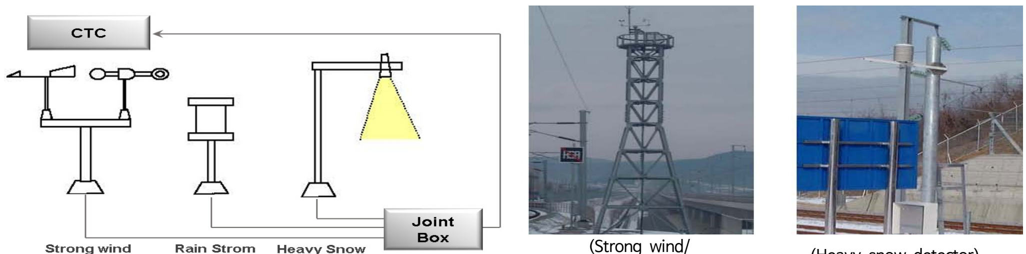
8.4. Weather Detectors

- Weather detectors detect weather conditions (rain storms, strong wind, heavy snow, etc.) and transmit the measured values and alarms to the CTC.

- Installation locations of weather detectors:
  - At intervals of about 20 km along the new high-speed line

- Safety measures when major weather conditions become worse
  - Rain storms: 35 mm or more per hour or 150 mm or more per day continuously → Slowing down to below 90km/h
  - Wind velocity: 45m/s or faster → Train operation is suspended or stopped.
  - Heavy snow: If the rail faces are covered with snow and are not to be seen → Slow down to below 30km/h

Figure 87 | Overview of Weather Detectors



(Strong wind/ rain storm detector)

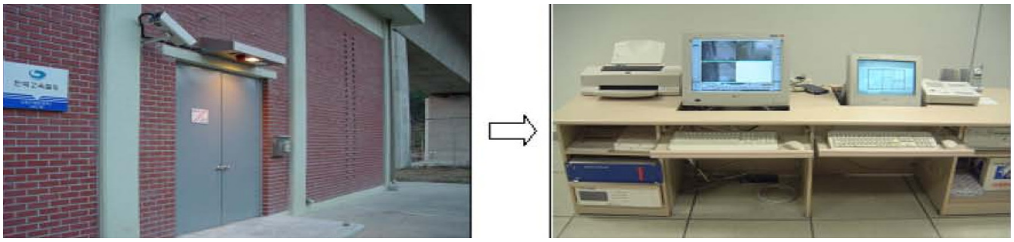
(Heavy snow detector)

Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.5. Remote Monitoring Equipment

- In the unmanned signaling machine room for a high-speed rail, CCTVs, proximity sensors, emergency sirens, card reader controllers, etc. are installed so that the central supervisory board can control and manage unauthorized visitors and the like efficiently.

Figure 88 | Remote Monitoring Equipment

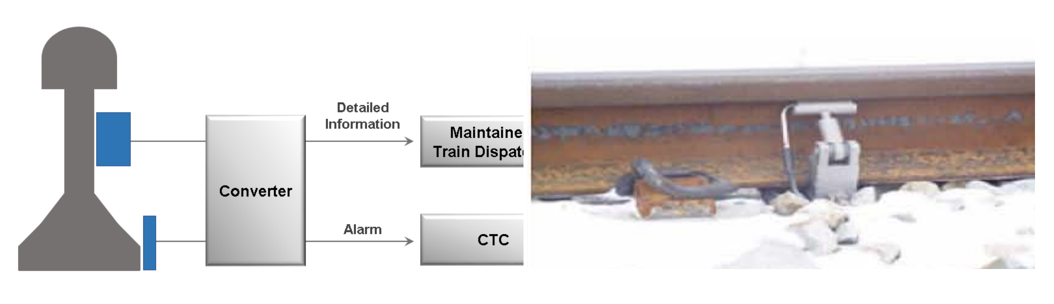


Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.6. Rail Temperature Detectors

- These detectors detect the temperature of rails in summer and transmit the information to the maintenance center and the operation commander.
- Actions to be taken when detecting an abnormal rail temperature:
  - 40℃ or above: simple alarm
  - 55℃~59℃: 230km/h or less
  - 60℃~65℃: 70km/h
  - 64℃ or above: Train operation stops.

Figure 89 | Overview of Rail Temperature Detectors

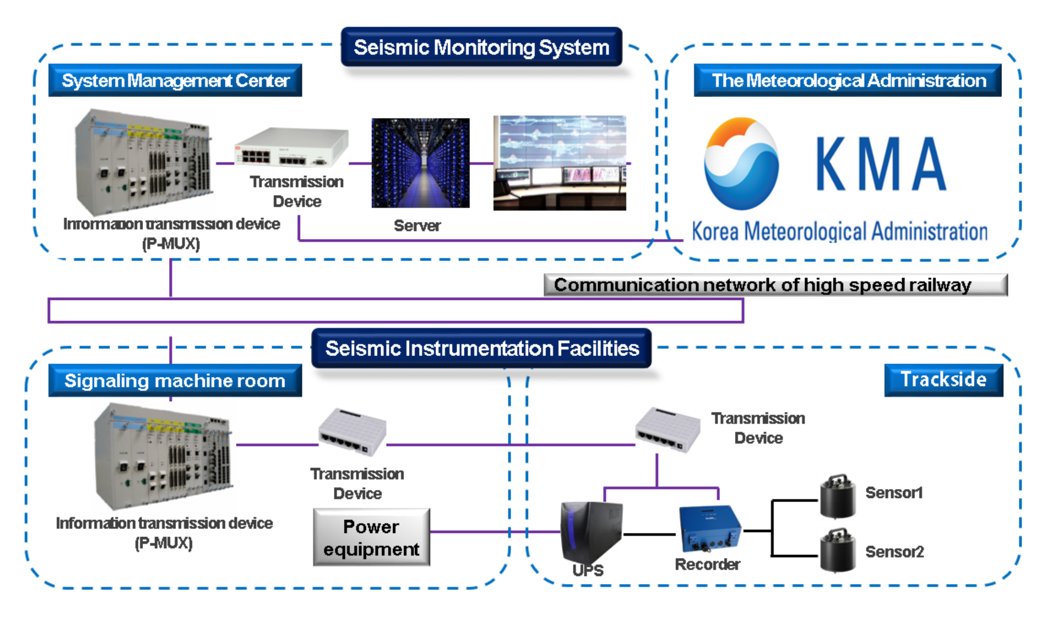


Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.7. Earthquake Detectors

- Earthquake detecting sensors are installed on the bridge and tunnel structures along the trackside of the HSR, and when an earthquake takes place, alarms are issued within four seconds with the train operation controlled promptly, thereby minimizing the seismic damages.
  - Yellow alarm (40gal or above): The train runs at a speed of 90km/h or less for the first time. Red alarm (60gal or above): The train operation stops.

Figure 90 | Overview of Earthquake Monitoring System & Measuring System

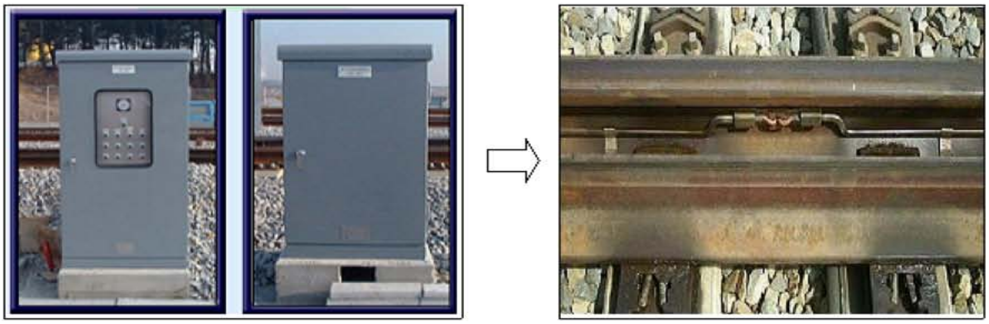


Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.8. Track Switch Heaters

- CTC/LCP operators or maintenance personnel generate heat using these heaters when the rails at turnouts are feared to be frozen due to snow, hail, etc.

Figure 91 | Track Switch Heaters

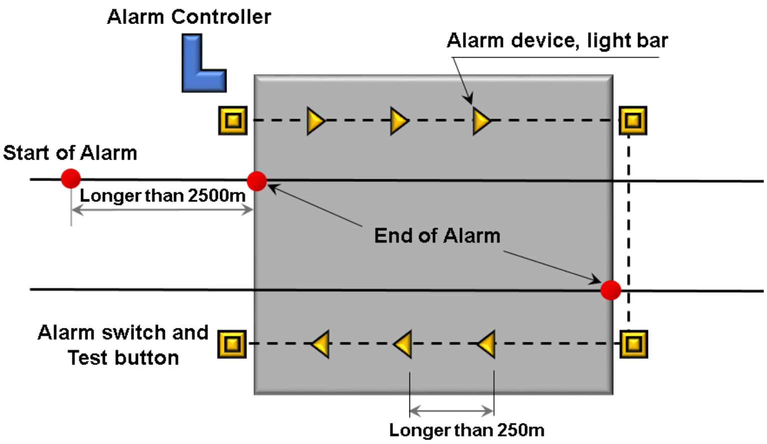


Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.9. Tunnel Alarm Devices

- When a train approaches a tunnel, the alarm speaker or warning light device is activated in order to protect the workers in the tunnel.

Figure 92 | Tunnel Alarm Devices



Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

- Ordinarily, the alarm devices do not work.

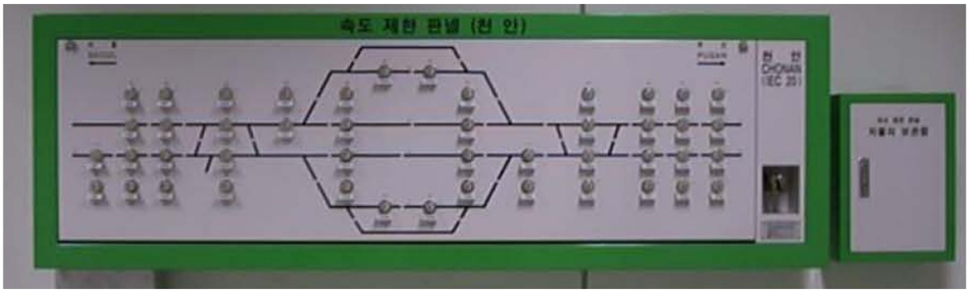
- After checking the function by handling the test button and the activation button, the worker should enter the tunnel.
  - When the train enters the approach block, the alarm device and warning light device are activated.
  - When the train enters the entrance of the tunnel, the alarm ends.
  - When the train runs out of the exit of the tunnel, the warning light turns off.

  * Alarm time between the start point of alarm and the entrance of the tunnel: 30 sec. for 300km/h and 53 sec. for 170km/h

8.10. Speed Limit Panels

- If the worker handles the speed limit switch installed in the signaling machine room when performing maintenance works along the trackside, the speed in the zone concerned is limited by ATC system.

Figure 93 | Speed Limit Panel

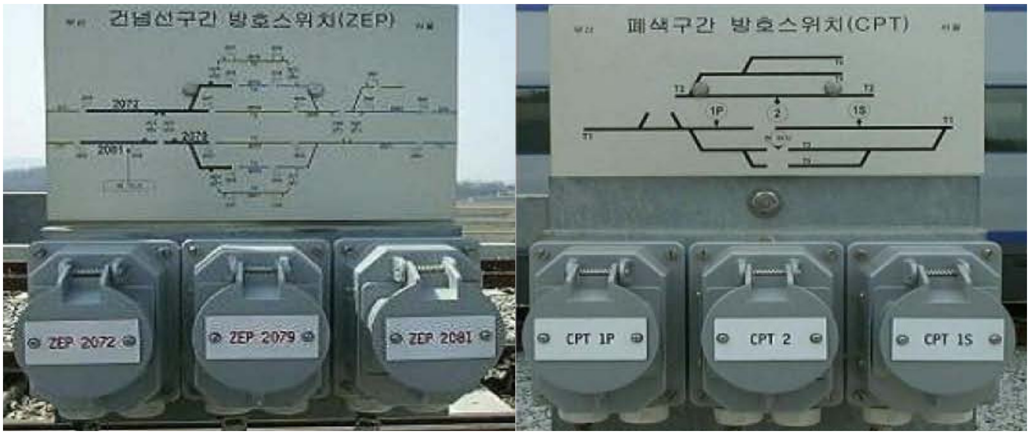


Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.11. Station Yard Protection Switch (TZEP), Block Section Protection Switch (CPT)

- When a maintenance worker is working in the track after obtaining a work permit from the operation commander, if this switch is handled to protect him, the train is kept from entering the track concerned.

Figure 94 | Station Yard & Block Section Protection Switches



(Station yard protection switch) (Block section protection switch)

Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

8.12. Devices for Permitting Repairers to Cross the Track

- When a worker crosses the high-speed track, he checks for the approach of a train in advance in order to ensure his safety.

Figure 95 | Overview of the Device for Permitting the Repairers to Cross the Track

- Component facilities: Traffic lights, check-up buttons
- Activation principles (Turned off in normal time) 〈When handling the bottom〉
  - If no train is within the approach block, the light is green.
  - If there is a train in the approach block, the light is red.

  *Crossing time: 20 sec./person

  (Min. approach block: 300 km/h x 20s = 1660 m)

Source : Korea Rail Network Authority, Publicity Material of Ho-Nam HSR, 「http://www.kr.or.kr」

9. Train Operation Plan

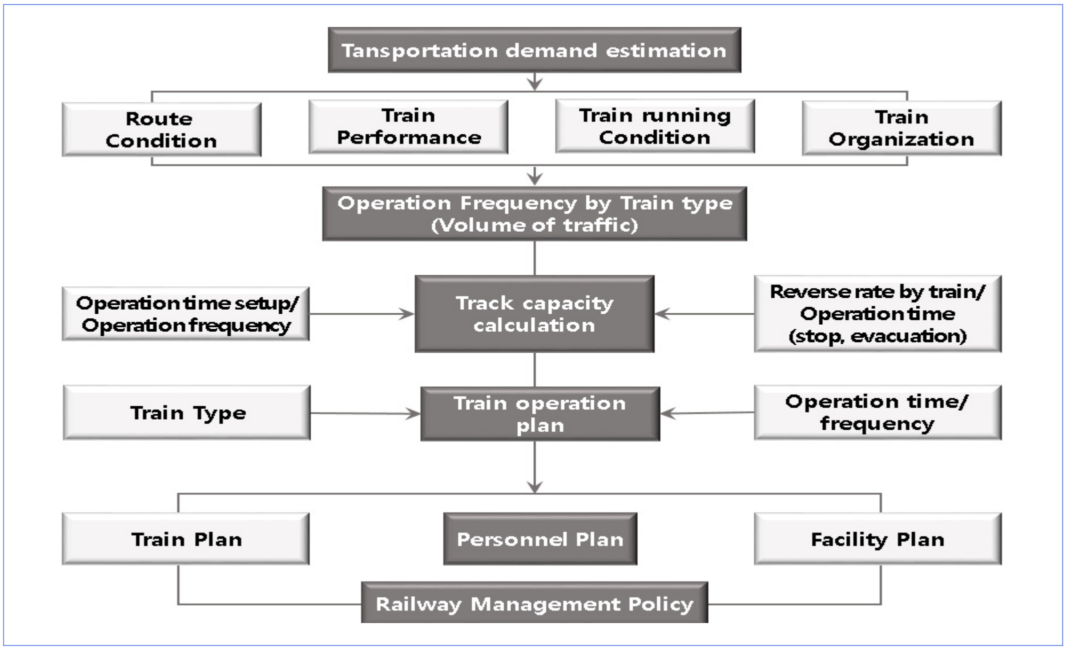
9.1. Overview

- A train operation plan serves as the foundation for determining if the forecast travel demand can be satisfied by the carrying capacities of the trains, coping with the change in the yearly travel demands and establishing a yearly rolling stock procurement plan accordingly.

- A train operation plan may be created differently in accordance with the features of transportation in the aspect of demand including the objects to be transported, travel demand of each section of the route, and maximum daily demand, and in the aspect of facilities including the alignment condition of the route, inter-station distances, station track layout, facility conditions, and signaling method, and various conditions such as vehicle performance including the tractive capacity of power cars, loading capacities of passenger cars, types of the trains to be operated and the difference in operating speeds.

9.2. Train Operation Analysis Flow Chart

Figure 96 | Train Operation Analysis Flow Chart



9.3. Train Operation Plan

9.3.1. HSR R/S Performance

• The rolling stock to be operated for the HSR in Myanmar has been planned on the premise of the operation of South Korea's KTX-Sancheon.

KTX-Sancheon	Major Specs. of the R/S	
	Train Consist	A 10-car trainset (PC×2+ET×2+T×6)
	Commercial Max. Speed	300 km/h
	Train Length	About 201m (1 train)
	Width of the Car Body	Power car 2.814m; Passenger car 2.970m
	Tractive power/ Braking power	210kN / 168kN
	Acceleration/ Deceleration	1.62km/h/s, 3.8km/h/s
	Load	434 t (fully loaded), 403 t (empty)

9.3.2. Review of the Carrying Capacities of a HSR

• For the business hours, South Korea's HSR business hours have been calculated and applied.

Table 157 | South Korea's HSR Business Hours

Category		Start of Operation	End of Operation	Business Hours	Remarks
Present Project		06:00 AM	23:00 PM	16 hours	1-hour lunch time
Gyeongbu Line	Up	05:10 AM	23:00 PM	16 hours 50 min.	
	Down	04:45 AM	22:20 PM	16 hours 35 min.	

Note) Based on the departure time at the starting station (960 min./day).

- Boarding rates: The boarding rate of South Korea's Gyeongbu HSR is 60~95%, and for this project, a boarding rate of 95% has been applied.

- Train consist and capacities: KTX-Sancheon (A 10-car trainset)

Table 158 | KTX-Sancheon (10-car train) Train Consist & Capacities

(Unit: persons)

Category	10-car Train (KTX-Sancheon)											Sum
Consist	Total	PC1	ET1	T2	T3	T4	T5	T6	T7	ET8	PC2	10 cars
Capacity	363	0	38	48	53	23	48	53	48	48	0	363

9.3.3. Review of Trainset Requirements

- The method of calculating the trainset requirements based on operating time is as follows:

- Calculation of Trainset Requirements

$$N = (2T + t) \times \frac{1}{P}$$

N=No. of operating trainsets T: Scheduled time (min.) t=Turnback time at the stations at both ends (min.) P=Min. operating headway (min.)

$$Nt = N \times C \times (1 + a)$$

Nt=Total no. of required cars N=Required no. of operating trainsets C=No. of cars per trainset a=Reserve ratio of 12%

Table 159 | Required Nos. of Trainsets for the Yangon~Mandalay HSR

Category	Operating time (min.)	Turnback time (min.)	Headway (min.)	Required no. of trainsets	Reserve no. of trainsets	Total no. of trainsets
Stopping at every station	148	40	12	32	4	36

*A reserve rate of 12% applied

9.3.4. Train Operation Simulation (TPS)

Table 160 | Yangon~Mandalay Simulation Conditions

Item	Stopping at every station	Stopping at foothold stations
Track length	596.0km	596.0km
Stations	7 nos.	3 nos.
Business hours	06:00~23:00 (16 hours in total)	06:00~23:00 (16 hours in total)

Table 161 | Yangon~Mandalay R/S Spec.

Category	Description	Category	Description
Train consist	10-car trainset (KTX-Sancheon)	Train length	Power car 22.7m, End passenger car 21.8m, Intermediate passenger car 18.7m
Max. operating speed	300km/h	Width of a car body	Power car 2.814m, Passenger car 2.97m or below
Weight of an empty train	403 t or below	Axial load	17 t or below

9.3.5. TPS Analysis Results for the HSR in Myanmar

- TPS has been calculated based on an ideal train operation with KTX Sancheon's max. operating speed of 300 km/h and the alignment and track conditions mentioned earlier.

Table 162 | Yangon~Mandalay Train Operation Time

Section		Inter-station distance (km)	Travel time (min.)	Schedule speed (km/h)
Stopping at every station	Yangon - Mandalay	596.0	148.0	241.6
Stopping at 2 stations	Yangon - Mandalay	596.0	128.0	279.4

Table 163 | Yangon~Mandalay TPS Analysis Result: Stopping at Every Station

Section	Distance(km)	Time(min.)	Speed(km/h)	Remarks
Yangon~Bago	68.0	17.0	240.0	
Bago~Pyu	135.5	30.5	266.6	
Pyu~Taungoo	50.0	13.0	230.8	
Taungoo~Naypyit	106.0	24.5	259.6	
Naypyit~Thazi	112.5	26.0	259.6	
Thazi~Kyaukse	85.0	20.0	255.0	
Kyaukse~Mandala	39.0	11.0	212.7	
	596.0	148.0	241.6	6-min. stop

Figure 97 | Operation Diagram in Case of Stopping at Every Station

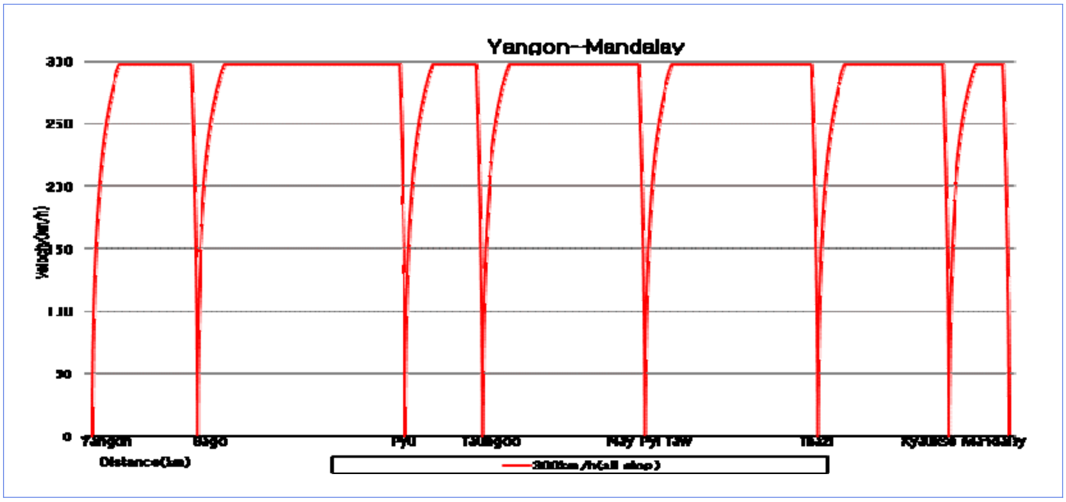
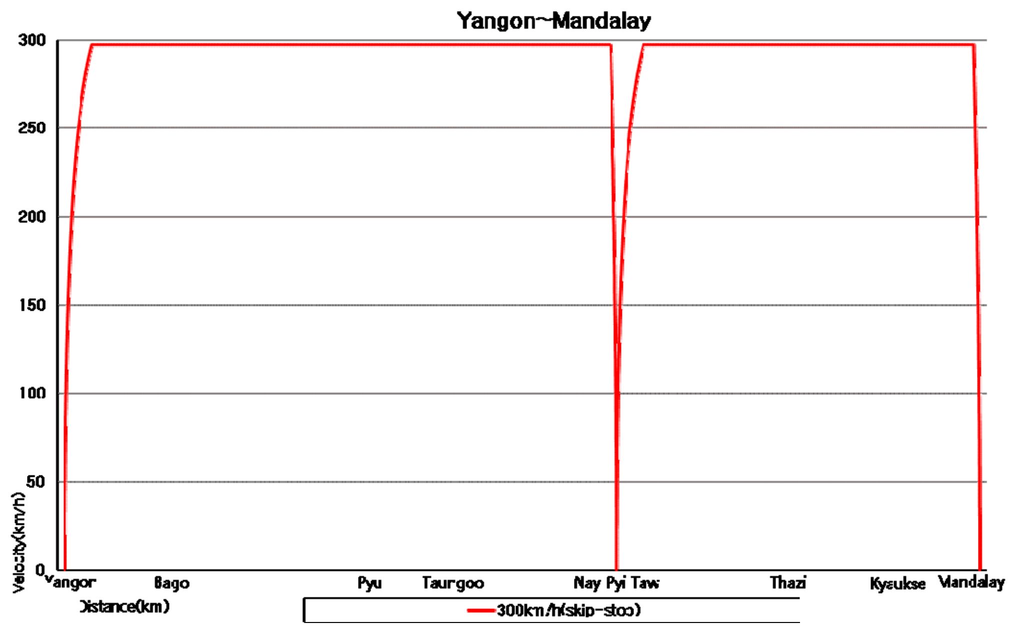


Table 164 | Yangon~Mandalay TPS Analysis Result: Stopping at Yangon, Naypiytaw, and Mandalay

Section	Distance(km)	Time(min.)	Speed(km/h)	Remarks
Yangon~Naypyitaw	359.5	76.0	283.8	
Naypyit~Mandala	236.5	51.0	278.2	
	596.0	128.0	279.4	1-min. stop each

Figure 98 | Operation Diagram in Case of Stopping at Naypyitaw Station



10. Project Cost Estimation

10.1. Overview

To estimate the project cost, decisions need to be made regarding surveying and geotechnical investigation, detailed route and alignment plans, structure types, system types and the like. As, however, these go beyond the scope of this study, the high-speed rail construction project cost for Myanmar will be roughly estimated and presented based on some assumptions and Korean cases.

The project cost estimate has been based on the costs of roadbed, systems and rolling stock analyzed for the construction of Honam HSR in South Korea (Korea Rail Network Authority, 2009), and the unit rates have been estimated by referring to the labor cost and overhead as per the Myanmar Mandalay-Myitkyina Railway Rehabilitation and Modernization Feasibility Study (K-EXIMBANK, 2016) carried out recently as an EDCF project of South Korea.

Particularly, in the case of roadbed and architectural construction costs, the ratio of labor cost takes up about 40%. Of this, for general laborers, the labor cost of Myanmar has been incorporated while for management officers with expertise, that of South Korea has been incorporated. And in the case of system construction cost, as the ratios of materials and equipment are high, the unit rates of Honam HSR have been incorporated as they are.

The roadbed construction cost of the Yangon~Mandalay project varies with the ratios of earthworks, bridges and tunnels. As in Myanmar, there are few mountainous areas and tunnels need to be constructed only in some sections where the route goes through downtowns, it has been estimated at 3%. Bridges are applied to areas with rivers, downtowns and the potential of multi-level crossings with roads. And at present, as the downtowns in the project area are fewer than those in South Korea, it has been estimated at about 25%. And the remaining 72% has been applied for earthworks. The average roadbed ratios of the Gyeongbu and Honam HSRs in South Korea have been analyzed to be at-grade 36.6%, bridges 32.8% and tunnels 30.6%.

In case of the R/S procurement cost, train operation plan based on demand forecast from Yangon to Mandalay(2040, standard) was briefly established and the quantity of R/S procurement based on the number of formation of train operation was calculated. The unit rates of KTX II in South Korea have been applied to unit rates of R/S.

In addition, the project costs for the construction of Gyeongbu, Honam, and capital-regional HSRs in South Korea and the unit project costs for the feasibility studies of HCMC-NHA TRANG, HANOI-VINH in Vietnam, which had been carried out as ODA projects of South Korea, have been analyzed, converted into the unit rates in 2016 of South Korea and then compared with the project cost of the Myanmar Yangon~Mandalay HSR.

10.2. Project Cost Estimate

- The estimated project cost has been divided into direct construction costs (roadbed, architecture, trackwork, signaling, telecommunication, power supply and R/S depots), consulting fees, R/S procurement cost, and land compensation cost.

- The Yangon~Mandalay HSR construction project cost has been estimated at approx. 20.4 billion USD.

Table 165 | Yangon~Mandalay HSR Construction Project Cost Estimate

Item		Q'ty	Unit	Unit Rate		Sum (Mill. USD)	Remarks
				Honam HSR (Mill. USD)	Yangon~Mandalay (Mill. USD)		
A. Direct construction cost						14,969.87	
Road bed	Earthworks	435.14	km	11.93	9.43	4,103.53	
	Bridges	151.09	km	39.18	30.98	4,680.71	
	Tunnels	18.13	km	23.33	18.44	334.39	
	Stations					138.87	
	At-grade stations (M)	6	Ea	17.57	13.89	83.32	
	At-grade stations (L)	2	Ea	35.13	27.77	55.55	Yangon, Mandalay
	Subtotal					9,257.51	
2. Architecture						242.64	
2.1 Medium-sized station buildings		6	Ea	33.96	26.85	161.10	
2.2 Large station buildings		2	Ea	51.56	40.77	81.53	Yangon, Mandalay
3. Trackwork						1,709.02	
3.1 Concrete track		1,208.72	km	1.36	1.36	1,648.06	Main tracks
3.2 Ballast track		67.09	km	0.91	0.91	60.96	Sidings
4. Signaling		604.36	km	1.25	1.25	756.87	
5. Telecom		604.36	km	1.32	1.32	798.38	
6. Power supply		604.36	km	2.73	2.73	1,651.51	
7. R/S depots		2	Ea	276.97	276.97	553.94	
B. Consulting fee						1,422.14	9.5% of direct constr. cost
C. R/S procurement cost						917.20	360cars
D. Direct project cost (A+B+C)						17,309.20	
E. VAT						1,730.92	10% of direct project cost
F. Land acquisition & compensation						1,323.64	6.5% of total project cost
G. Total project cost						20,363.77	

10.3. Comparison of Project Costs

- At the time of construction in South Korea, the per-km costs of different HSRs were similar to one another as 38.8~43.5 million USD, but if they are converted considering the price escalation based on 2016, it is 39.8~61.9 million USD, which indicates that there are differences with projects. The reasons why the Gyeongbu HSR project cost was relatively higher include the upgrade of existing lines by phase, connection line projects considering the increased use of high-speed rails, and the construction R/S depots considering the additional construction of HSRs in the future.

- The reasons why the Honam HSR project cost was lower than the Gyeongbu HSR project cost are considered to be the optimization of structural sizes such as the reduction of sectional areas of tunnels and bridges, application of passenger-only train load, minimization of new rolling stock procurement, and not reflecting of the costs of existing line upgrade and connection line creation.

- The Yangon~Mandalay project per-km cost is 33.7 million USD, which is lower than in South Korea. The reason is that for general laborers working in roadbed and building construction sites, the current labor cost of Myanmar is incorporated and that the number of structures such as tunnels and bridges is small because the terrain of the project area is mostly flat.

- The per-km cost as per the FS of the Vietnam HSR construction project is 35.4~38.2 million USD, which is slightly higher than the estimated cost of the Yangon~Mandalay HSR project.

Table 166 | Comparison with the Yangon~Mandalay HSR Project Cost

Project	Design Speed (km/h)	Length (km)	Construction Period	Project Cost (mill. USD)	
				At the time of construction	in 2016
Gyeongbu HSR (South Korea)	350	418.7	1992-2016	17,915 (1km≒42.8)	25,918 (1km≒61.9)
Honam HSR Section 1 (South Korea)	350	182.3	2006-2016	7,072 (1km≒38.8)	7,246 (1km≒39.8)
Capital-region HSR (South Korea)	350	61.1	2008-2017	2,659 (1km≒43.5)	2,735 (1km≒44.8)
HCMC-NHA TRANG Line (Vietnam)	350	373.7	F/S(2010), KOICA	12,058 (1km≒32.2)	13,246 (1km≒35.4)
HANOI-VINH Line (Vietnam)	350	334.2	F/S(2008), KOICA	11,239 (1km≒33.6)	12,757 (1km≒38.2)
Yangon-Mandalay HSR (Myanmar)	350	604.4	F/S(2017), EDCF	20,364 (1km≒33.7)	20,364 (1km≒33.7)

Note) Based on a middle year of the project period and considering the price escalation in South Korea, the project costs have been converted into the costs in 2016.
Sources) KRNA, 「Rail business explanatory data」, 2017
KOICA, 「FS Report on Vietnam Nazang~Ho Chi Minh Rail Double-tracking」, 2010

11. Transport Demand Forecast for the HSR in Myanmar

11.1. Methodology for Transport Demand Forecast

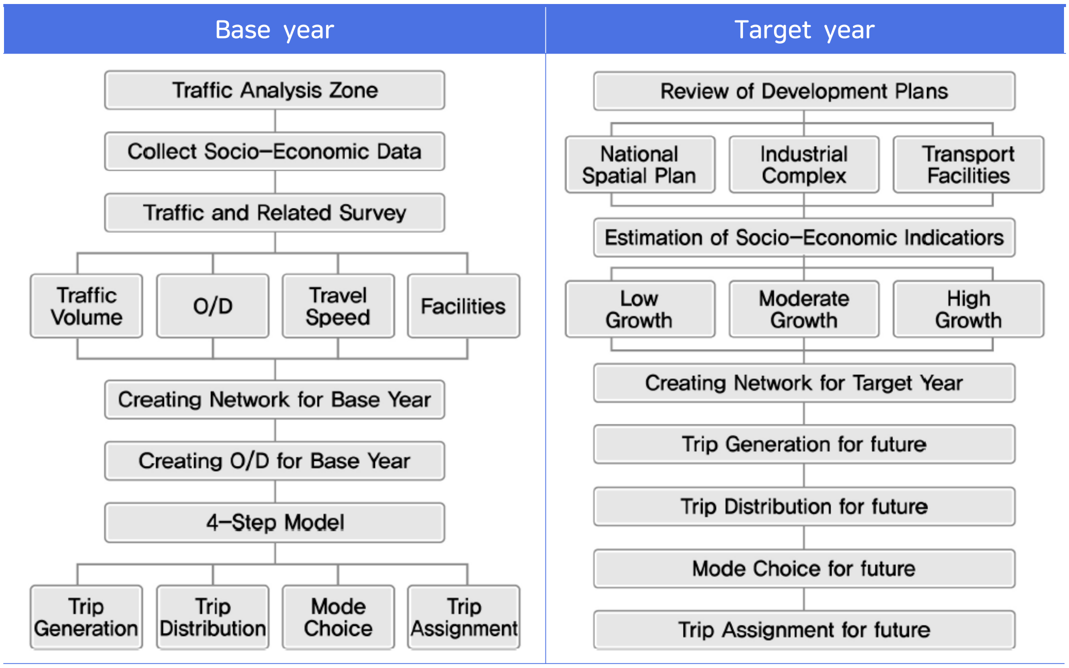
- In this section, the travel demand of the users of the new HSR between Yangon and Mandalay in Myanmar is forecasted. Basically, for transport demand forecast, a four-step forecast model is used most commonly, and for this study, the four-step model has been applied. The four-step demand forecast model consists of trip generation, trip distribution, modal split (mode choice) and trip assignment, and for each of them, various techniques have been developed.

Table 167 | 4-step Demand Forecast Model

Step	Purpose	Techniques
Trip generation	• Estimating the origin and destination traffic volumes	• Growth factor method, Cross-classification analysis, Regression Analysis
Trip distribution	• Producing O/D by distributing the origin and destination traffic volumes to traffic zones	• Growth factor model, Gravity model, Entropy maximization model
Mode choice	• Sub-dividing the O/D between traffic zones to specific modes of transportation	• Trip-end model, Trip-interchange model, Activity based model, Diversion curve analysis
Trip assignment	• Assigning the O/D of each mode of transportation to the transport network in the project area	• All-or-Nothing assignment, Incremental assignment

- The four-step demand forecast model predicts the demand based on the trips between traffic zones. An area in a certain range is set as a zone, and the analysis is made based on the trips between the zones. Thus, the most fundamental tasks of the demand analysis are the division of traffic zones and the establishment of transport networks. In this section, the already-established data were modified and improved in accordance with the zone system set during the previous study KOICA, Myanmar Arterial Road Network Master Planning Project, 2016, and by establishing a rail network through additional surveys, the demand forecast has been carried out. For the future transport demand, the passenger traffic volume of each mode of transportation has been forecasted by incorporating some economic growth scenarios with different annual average GDP growth rates into the transport demand model of each step established. The demand forecast process as per the 4-step demand forecast model is as shown below.

Figure 99 | Transport Demand Forecasting Process



Source: Yooshin Engineering, Myanmar Trunk Road Network Master Planning Project, 2016

11.2. Myanmar Yangon~Mandalay Transport Demand Forecast

11.2.1. Analysis Condition Setting & Basic Data Establishment

- In this study, transport demand has been forecasted through a 4-step transport demand forecast process. The analysis was conducted by setting the base year for the analysis as 2015 and the opening year as 2030. The modes of transportation for the demand forecast have been divided into five modes in total—cars, buses, conventional rails, airplanes and the high-speed rail. It is assumed that there is no traffic volume generated by the construction of the HSR, and that the total traffic volumes before and after the HSR construction are the same.

1) Setting of Analysis Years

- By establishing a trip origin / destination model using future populations and GRDP growth rates, the HSR demand for traffic volumes in each future year has been forecasted.

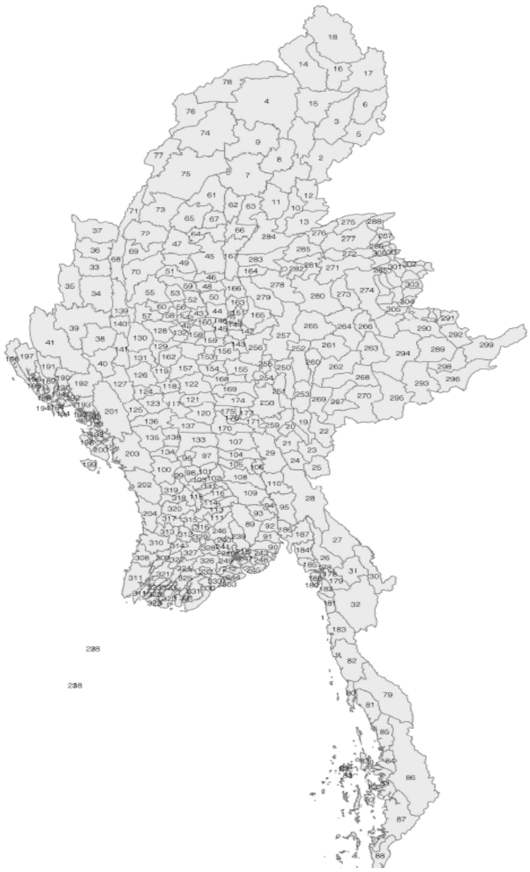
- Opening year: 2030
- Target years: 2030, 2040, 2050 and 2060

2) Setting of Traffic Zones

- For the transport demand forecast, the following method is applied: forecasting the traffic volume in units of traffic zones and assigning them to each path. As in the case of the present study, the road O/D and Network already established by the previous study have been reviewed and supplemented, 345 traffic zones have been set, which is the same as in the previous study.

- 333 Townships plus 12 external zones equal 345 zones in total

Figure 100 | Traffic Zoning Map



Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project」, 2015

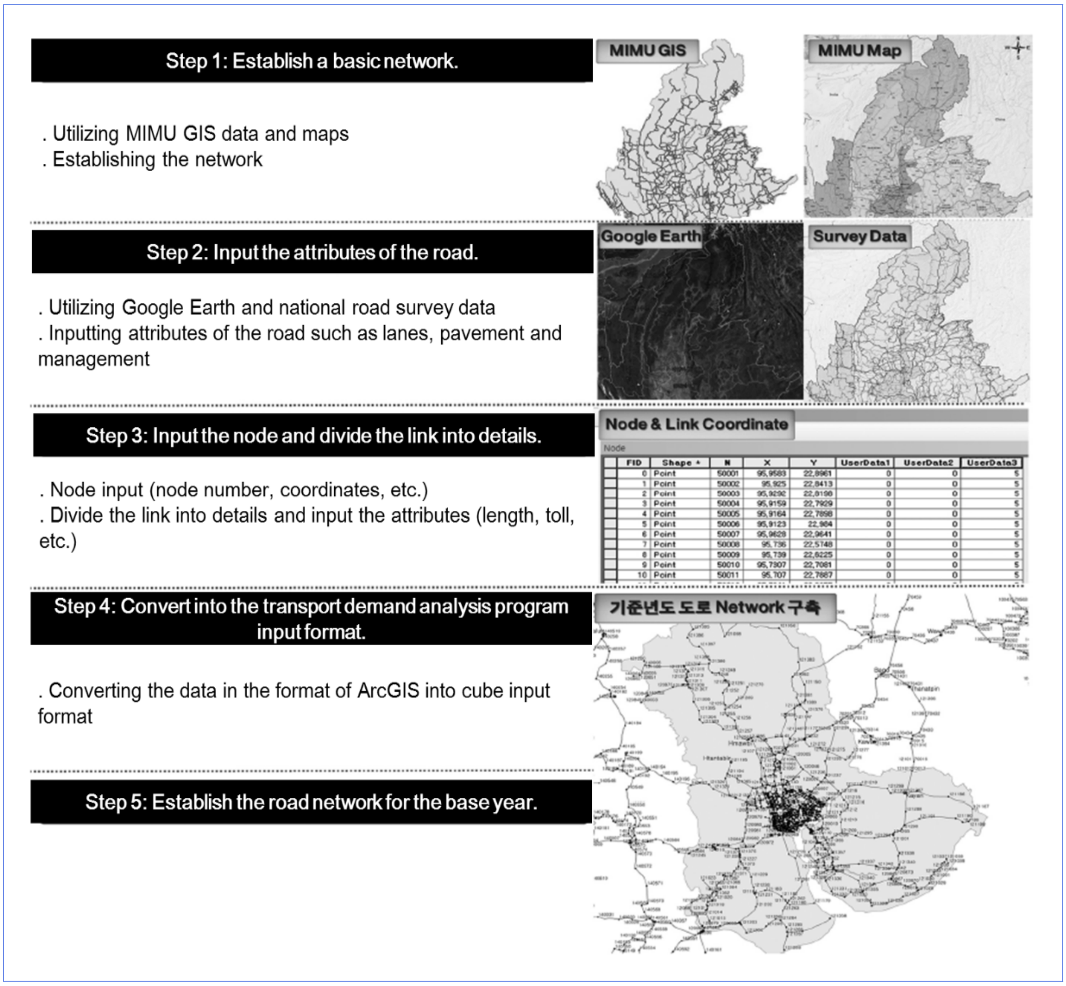
3) Establishment of the Network

a) Establishment of the Road Networks

1. Establishment of the Network for the Base Year

- The road network has been established by utilizing MIMU (Myanmar Information Management Unit) GIS data, country maps, and national road survey result data and converting them into node- and link-based data.

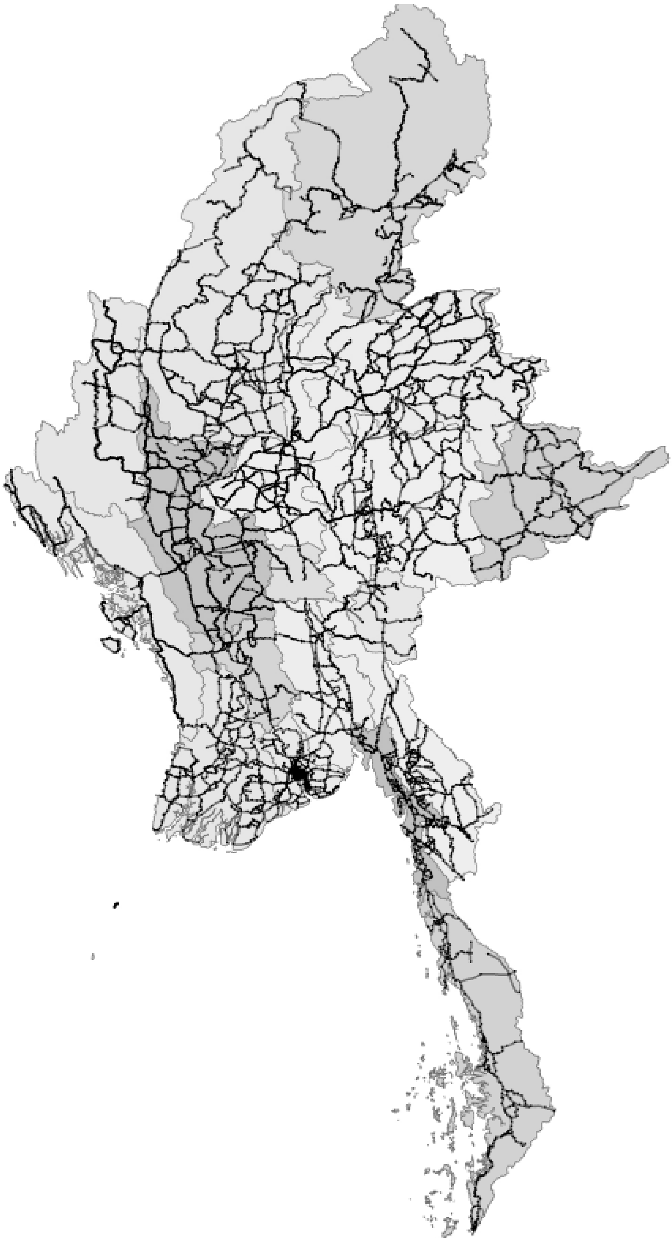
Figure 101 | Road Network Establishing Method



Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project」, 2015

- The road network in the base year has been established with a total length of 81,072km and 23,434 links.

Figure 102 | The Resulting Road Network



Source: Yooshin Engineering, Myanmar Trunk Road Network Master Planning Project, 2016

b) Networks for Future Years

• The road networks for future years have been incorporated in accordance with the opening year of the current road development project.

Table 168 | Road Lengths Incorporating the Future Road Network

Target Year	Lengths Incorporated
2020	• Expressway: 558km • Major trunk road: 2,794km • Auxiliary trunk road: 347km • Sum: 3,699km
2025	• Expressway: 1,723km • Major trunk road: 4,856km • Auxiliary trunk road: 1,041km • Sum: 7,620km
2035	• Expressway: 3,851km • Major trunk road: 9,029km • Auxiliary trunk road: 2,429km • Sum: 15,309km
After 2035	• Expressway: 9,470km • Major trunk road: 13,225km • Auxiliary trunk road: 11,683km • Sum: 34,378km

Note: The lengths from the year 2025 are cumulative lengths including those from 2020.
Source: KOICA, 「Final Report on Myanmar Trunk Road Network Master Planning Project」, 2015

c) Establishment of the Rail Network

1. Network for the Base Year

• Like the road network, the rail network setup can be divided into basic network setup, which consists of nodes and links, and the line data setup which reflects the present rail lines. In this study, the rail network and line data have been established by utilizing the network data from the previous study and the data possessed by Myanmar Railways (MR). The node setup of the rail network, which is the very fundamental task, is a process of inputting the attributes and locations of railway stations into the network. The locations of railway stations have been established using Google Earth and maps. After that, the rail network was set up by connecting the links to the nodes established and then inputting the inter-station distances and the type of the route provided by MR as attributes. The line data have been established based on the data furnished by MR as a process of inputting the vehicle operation headways, scheduled speeds and stopping stations of each route. The following data have been provided by MR, and in this study, the line data have been established utilizing them..

Figure 103 | Myanmar Rail Network Setup Process

Tran No.	Type of Service	Average Scheduled Speed Mile/hrs	Running Hours	Stations	Distance between Stations (Miles)
3Up/4Dn	Express	30.00	1' 41"	Yagon-Bago	46.50
		35.50	1' 07"	Bago-Daiku	34.75
		36.00	16"	Daiku-Pyuntaza	6.50
		36.00	13"	Pyuntaza-Nyaunglebin	5.00
		36.00	1' 39"	Nyaunglebin-Phyu	41.50
		33.00	56"	Phyu-Taungoo	31.75
		35.70	2' 27"	Taungoo-NayPyiTaw	67.00
		32.70	2' 57"	NayPyiTaw-Tharsi	73.00
		36.00	2' 54"	Tharsi-Mandalay	79.50
5Up/6Dn	Express	30.00	1' 41"	Yagon-Bago	46.50
		35.70	4' 05"	Bago-Taungoo	119.50
		35.70	2' 30"	Taungoo-NayPyiTaw	67.00
		32.70	2' 36"	NayPyiTaw-Tharsi	73.00
		36.00	2' 49"	Tharsi-Mandalay	79.50
11Up/12Dn	Express	30.00	1' 45"	Yagon-Bago	46.50
		38.50	1' 07"	Bago-Daiku	34.75
		36.00	19"	Daiku-Pyuntaza	6.50
		36.00	16"	Pyuntaza-Nyaunglebin	5.00

Current Routes & Their Attributes in Myanmar

```
t lines init
a '1' e 7 360 56,32 'YM' 10,91 35,08 2017
 ttf=91 dwt=1,00 150001 150006 150008 150009 150010 150015
 150019 150025 150030 150038 lay=0

a '2' e 7 270 54,72 'MY' 10,90 35,08 2017
 ttf=91 dwt=1,00 150038 150030 150025 150019 150015 150010
 150009 150008 150006 150001 lay=0

a '3' e 7 216 56,32 'YM1' 10,91 35,08 2017
 ttf=91 dwt=1,00 150001 150006 150019 150025 150030 150038 lay=0

a '4' e 7 180 54,72 'MY1' 10,90 35,08 2017
 ttf=91 dwt=1,00 150038 150030 150025 150019 150006 150001 lay=0

a '5' e 7 98,18 56,32 'YM2' 10,91 35,08 2017
 ttf=91 dwt=1,00 150001 150006 150008 150009 150010 150015
 150019 150025 150030 150038 lay=0

a '6' e 7 90 54,72 'MY2' 10,90 35,08 2017
 ttf=91 dwt=1,00 150038 150030 150025 150019 150015 150010
 150009 150008 150006 150001 lay=0

a '7' e 7 154 56,32 'YN1' 10,91 35,08 2017
 ttf=92 dwt=1,00 150001 150006 150008 150014 150019 150020 150025 lay=0
a '8' e 7 135 54,72 'NY1' 10,90 35,08 2017

 ttf=92 dwt=1,00 150025 150020 150019 150014 150008 150006 150001 lay=0
a '9' e 7 35 56,32 'YN1' 10,91 35,08 2017

 ttf=92 dwt=1,00 150001 150006 150008 150014 150016 150019 150023 150025 lay=0
a '10' e 7 34 54,72 'NY2' 10,90 35,08 2017

 ttf=92 dwt=1,00 150025 150023 150019 150016 150014 150008 150006 150001 lay=0
a '11' r 1 999 49,89 'MailYM' 10,91 35,08 2017
```

Line Data for the Rails in Myanmar

d) Network for Future Years

- The future rail network has been established by incorporating the route and station plan for the HSR under this study and railway development projects such as the railway upgrade project bewteen Yangon and an area in Myanmar carried out by JICA. And the future transport demand has been forecasted by assuming that the network after 2035 will be the same.

e) Establishment of an Airport Network

• The method of establishing the air network is the same as that of establishing the rail network. The air network has been set up in accordance with the domestic flight schedule provided by a local firm in Myanmar. As a result of analyzing the domestic flight schedule, the air traffic is expected to occur from the routes between Yangno and Naypiytaw and between Yangon and Mandalay. Also, the line data for each section have been established and applied using the information on the origin and destination airports.Transport Demand Forecast for Myanmar

4) O/D Setup

a) Road O/D Setup

① Base-Year O/D Setup

• Trip generation is the first step of the traditional four-step transport demand forecast process. In this step, the traffic volume of humans or vehicles coming into or going out of a traffic zone is predicted. For road traffic, the trip generation has been forecasted through regression analysis, and 333 townships were bound into five groups, and then the regression model was established with the population of each group as an independent variable and the trip generation as a dependent variable.

Table 169 | The Trip Generation Regression Model Established

Category	Group 1		Group 2		Group 3		Group 4		Group 5	
	Factor	t-value	Factor	t-value	Factor	t-value	Factor	t-value	Factor	t-value
Population	0.0569	12.3	0.0325	21	0.0173	30.1	0.3375	10.3	0.1325	5.9
R^2	0.82		0.89		0.79		0.79		0.69	

Source: Yooshin Engineering, Myanmar Trunk Road Network Master Planning Project, 2016

Table 170 | Base year OD Table

Unit: Trips/day

OD	Ka chin	Ka yah	Ka yin	Chin	Sa gaing	Tanin tharyi	Bago	Mag way	Man dalay	Nay PyiTaw	Mon	Ra khine	Yangon	Shan	Ayeyarw ady	SUM
Kachin	3,667	50	0	0	192	0	1	0	8	0	0	8	0	108	3	4,037
Kayah	51	310	10	0	0	0	17	0	4	8	0	0	1	347	0	750
Kayin	0	10	1,555	0	1	9	154	2	1	532	498	1	58	2	0	2,824
Chin	0	0	0	313	297	0	0	142	6	0	0	172	1	0	0	931
Sagaing	181	0	1	296	7,816	5	2	551	1,667	3	2	4	63	25	1	10,618
Tanintharyi	0	0	9	0	3	2,421	1	0	0	0	101	2	57	0	0	2,594
Bago	0	13	153	0	1	1	4,724	418	31	294	60	35	3,582	6	176	9,494
Magway	0	0	2	141	540	1	445	3,785	1,084	159	0	92	12	12	39	6,313
Mandalay	7	4	2	5	1,655	0	42	1,093	12,657	388	0	2	17	797	0	16,669
NayPyiTaw	0	7	532	0	3	0	332	149	346	2,001	1,009	1	99	57	1	4,537
Mon	0	0	495	0	2	100	59	0	0	1,010	1,084	0	238	0	2	2,991
Rakhine	6	0	3	172	6	2	42	97	2	2	0	5,658	16	1	83	6,091
Yangon	0	1	56	0	52	55	3,499	9	12	82	233	14	211,662	2	3,320	218,997
Shan	108	352	2	0	28	0	9	13	822	67	0	2	4	10,932	1	12,340
Ayeyarwady	1	0	0	0	1	0	172	35	0	0	2	74	3,336	1	7,623	11,246
SUM	4,023	748	2,822	927	10,597	2,595	9,498	6,294	16,639	4,548	2,991	6,064	219,147	12,291	11,251	310,433

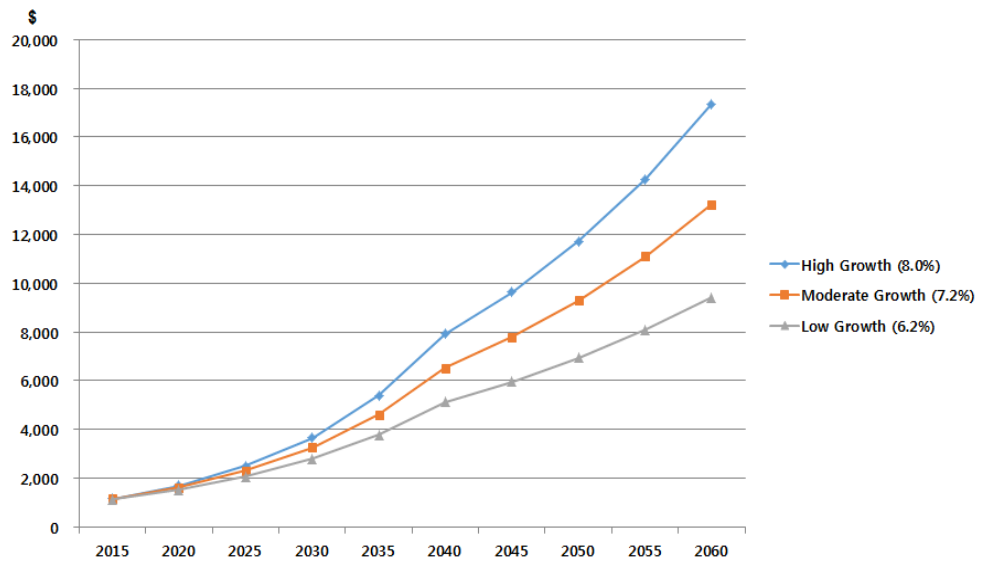
② Future-Year O/D Setup

- In this study, the moderate-growth (7.2%) scenario of the economic growth scenarios that MNPED (Ministry of National Planning and Economic Development) suggested in the 2nd Myanmar Development Cooperation Forum in 2014 was utilized to establish the O/D for future years.

- Also, in this study, the future O/D has been set up by setting some economic growth scenarios with different GDP growth rates. They are high-growth, moderate-growth and low-growth scenarios in accordance with GDP growth rates, and their details are as follows:
  - Scenario 1: High Growth (GDP growth rate 8.0%)
  - Scenario 2: Moderate Growth (GDP growth rate 7.2%)
  - Scenario 3: Low Growth (GDP growth rate 6.2%)

- As the GDP growth rate is anticipated to change with economic growth, a more practical O/D has been established by applying only half of the GDP growth rate for after year 2040.

Figure 104 | Economic Growth Scenarios



- For the base year, the trip generation was forecasted using population data, but because in a developing country, the growth rate of traffic volume is much higher than the population growth rate in general and the relationship with GRDP is higher, the future trip generation has been estimated by adding the variable of GRDP growth rates. For the regression analysis model applied for the future O/D setup in this study, the model suggested in the existing study presented above has been applied. As an explanatory variable, the population of each traffic zone has been adopted, and it has been set up by adding parameters that can reflect the explanatory variables and the GRDP growth trend.

$$Y_i = \beta_1 x_{i1} \times \beta_2$$

Where, Y_i: Total traffic volume in traffic zone i

x_{i1}: Explanatory variable of traffic zone i (population)

β_1: Estimated parameter

β_2 : Parameter of GRDP growth rate

Table 171 | Trip Generation Estimate by Economic Gorwth Alternative

Unit: Trips/day, %

Year	2030	2040	2050	2060
GDP Growth 8.0%	1,583,161	3,797,452	5,847,048	9,003,874
GDP Growth 7.2%	1,386,431	3,089,780	4,584,121	6,801,652
GDP Growth 6.2%	1,172,922	2,382,491	3,375,384	4,782,656

b) Railway O/D Setup

① Base-Year O/D Setup

- In this study, the origin and destination stations of travellers who use major stations between Yangon and Mandalay were surveyed through a local survey in Myanmar. The number of the survey spots was nine in total with 1,586 valid samples.

Table 172 | Local Survey Outcomes

Survey Spot	No. of Valid Samples
Mandalay	162
Phyu	211
Yangon	216
Taungoo	193
Pagu	197
Thazi	205
Kyaukse	198
Nay Pyi Taw	203
Pyinmana	1
Total	1,586

- For the railway O/D setup, the boarding information of each station between Yangon and Mandalay as provided by MR and the field survey results were utilized. To establish a more practical railway O/D, the number of survey samples for each station needed to be adjusted in scale, and to establish the trip O/D by the Township with the inter-station trip O/D, sub-division was performed additionally. The following is how to establish a railway O/D:

Figure 105 | Railway O/D Setup Process

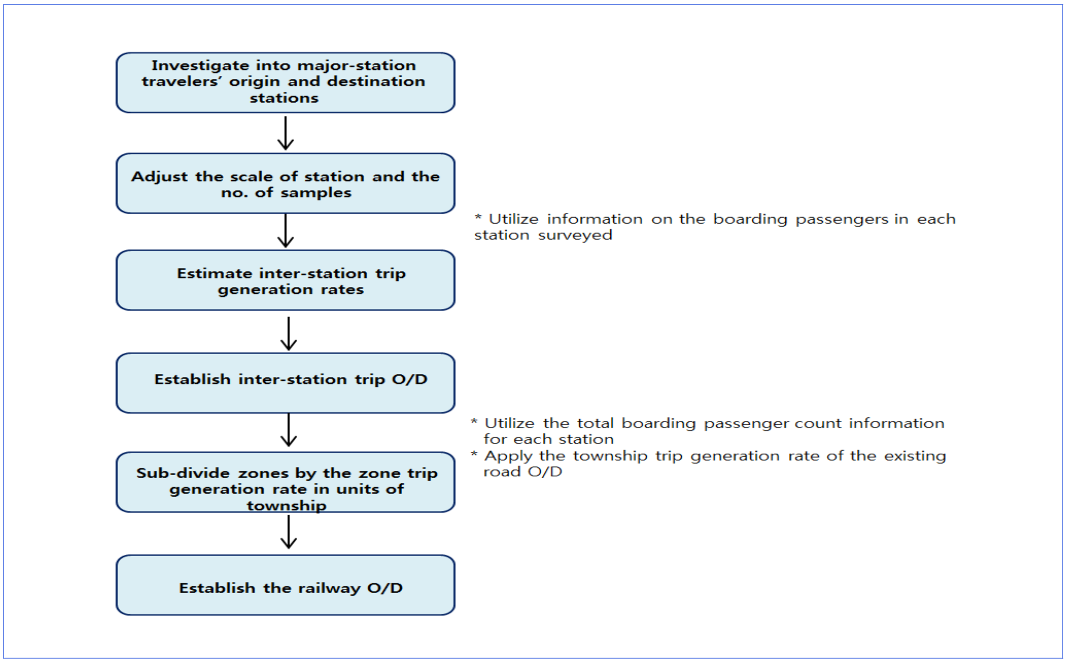


Table 173 | Base year OD Table (Rail)

Unit: Trips/day

OD	Ka chin	Kayah	Kayin	Chin	Sa gaing	Tanin tharyi	Bago	Mag way	Man dalay	NayPy iTaw	Mon	Ra khine	Yang on	Shan	Ayeya rwady	SUM
Kachin	0.3	0.1	0.1	0.1	0.6	0.2	0.4	0.4	0.4	0.1	0.1	0.3	53.5	0.9	0.4	58.1
Kayah	0.1	0.1	0.1	0.1	0.3	0.1	2.7	0.2	0.2	2.6	0.1	0.1	0.4	0.5	0.2	7.7
Kayin	0.1	0.1	0.1	0.1	0.3	0.1	0.2	0.2	0.5	0.1	0.1	0.1	53.2	0.5	0.2	55.8
Chin	0.1	0.1	0.1	0.1	0.3	0.1	0.3	0.2	0.3	0.1	0.1	0.2	0.4	0.5	0.2	3.0
Sagaing	0.6	0.3	0.3	0.3	4.2	0.4	50.9	0.9	36.3	576.6	0.3	0.6	3,050	7.3	1.0	3,730
Tanintharyi	0.2	0.1	0.1	0.1	24.4	0.1	0.3	0.2	1.8	0.1	0.1	0.2	0.5	0.6	0.3	28.8
Bago	0.4	0.2	0.2	0.3	76.3	0.3	2,071	0.7	91.9	717.6	0.3	0.5	16,222	7.5	0.7	19,190
Magway	0.4	0.2	0.2	0.2	0.9	0.2	3.2	0.6	1.0	1.9	0.2	0.4	71.5	1.4	0.6	82.9
Mandalay	0.4	0.5	0.2	0.3	31.3	0.3	47.8	1.2	31.2	58.9	0.3	0.5	793.0	1.6	6.3	973.8
NayPyiTaw	0.1	0.1	0.1	0.1	229.2	0.1	303.7	240.0	53.2	44.3	0.1	0.2	2,805	102.0	0.2	3,778.8
Mon	0.1	0.1	0.1	0.1	0.3	0.1	260.3	0.2	6.1	0.1	0.1	0.2	0.4	0.5	0.2	268.8
Rakhine	0.3	0.1	0.1	0.2	0.6	0.2	0.5	0.4	0.5	0.2	0.2	0.3	0.8	1.0	0.4	5.6
Yangon	0.7	0.4	0.4	0.4	2,088.0	0.5	18,242	428.0	139.1	5,549	0.4	0.8	31.1	1,136.6	1.2	27,619
Shan	0.9	0.5	0.5	0.5	2.1	0.6	8.3	1.4	2.1	0.5	0.5	1.0	55.4	3.4	1.5	79.3
Ayeyarwady	0.4	0.2	0.2	0.2	1.0	0.3	4.9	0.6	1.7	5.2	0.2	0.4	1.2	3.2	0.7	20.4
SUM	5.3	3.0	2.7	3.0	2,459.8	3.3	20,997	675.2	366.3	6,957	3.0	5.6	23,140	1,267.4	14.2	55,912

② Future--Year O/D Setup

- For the future railway O/D, the ODs in the years 2030, 2040, and 2050 have been established by applying the same model as for the future road O/D setup. In the case of the O/D in 2060, however, it is expected that there will be no significant change in the railway traffic volume after 2050. Thus, the future demand has been estimated by applying the same O/D as in 2050.

5) Air O/D Setup

a) Base-Year O/D Setup

- Based on the exhaustive survey on the travellers at the airports in Yangon, Mandalay, and Naypyitaw in Myanmar, the air O/Ds for Yangon~Mandalay and for Yangon~Naypyitaw have been set up.

6) Future-Year O/D Setup

- For the future railway O/D setup, the O/Ds in 2030, 2040, 2050, and 2060 have been set up by applying the GRDP growth rates, which is the same as the future road O/D setup method.

7) Mode Choice

a) Overview

- In this step, the share ratios of each mode of transportation in the traffic volumes between each origin and destination calculated through the steps of trip generation and trip distribution are forecasted. In this study, the share ratios of five modes in total—cars, buses, rails, high-speed rails and airplanes—have been predicted. As the project goes through the steps of trip generation and trip distribution by each mode, the O/Ds for four modes in total (cars, buses, rails and airplanes) are produced. If the high-speed rail is opened in the future, some users of the existing four modes will transfer to the high-speed rail. And one can say that estimating the quantity of modal change from any of the existing modes to the HSR when the HSR is opened, will be the key in the mode choice step.

• In this study, multinominal logit model, which determines choice options based on probability utility theory, is used to calculate the quantity of modal transfer. Multinominal logit model is to calculate the utility of each mode in accordance with the utility function of each mode and the mode choice probability in accordance with utility. Utility function is the modeling of the preference of a mode in accordance with travel time and travel cost. In order to develop the function, data on actual travel time by each mode, travel cost and the mode chosen are needed. As, however, there is no high-speed rail in Myanmar, it is impossible to utilize the observation data for the establishment of utility function. Therefore, the share ratios of modes are predicated by surveying users' stated preference after the opening of the HSR and by developing utility function.

b) a. Stated Preference (SP) Survey

• SP survey is a method used to identify the respondents' responses about the virtual situations which are impossible to observe as in the case of introducing a new mode, and then to predict the results. The SP survey in this study figures out users' potential stated preference in the way of choosing preferred modes from the existing mode used and the HSR when the HSR is opened in the future. The survey was made up chiefly of the survey of actual trip condition, in which the socioeconomic features and the actual condition of trips by travellers are identified and the SP survey in which travellers' preference about modes of transportation is figured out.

- The survey of the actual condition of trips contained the questions about the respondent's information (gender, income level, age, address), the purpose, frequency, time and cost of their trips by the existing mode (cars, buses, conventional rails and airplanes) and the like.
- The SP survey was composed in such a way that the respondents could choose their preferred mode by comparing the travel time and costs under each scenario for the existing means of trips and the HSR.
- In the case of travel time, the questions were so designed that the respondents could choose their preferred mode by comparing total travel times including in-vehicle time and out-of-vehicle time.
- The questionnaires are presented in the Appendix.

• As a high-speed rail is characteristically preferred for a long-distance trip than for a short-distance travel, differences in preference were shown depending on the travel distance. Thus, the questionnaires were classified into those for a travel distance of longer than 300 km and those for a distance of 300 km or less, and then, the former was presented to Yangon~Mandalay travellers and the latter to Yangon~Taungoo travellers. The total number of samples from the SP survey conducted in Myanmar is 480, of which

448 have been used as valid ones.

- Also, as the HSR is a high-speed and high-class rail service with expensive fare, the stated preference may vary with the respondents' income level. Thus, the survey was performed so that at least a certain number of samples might be secured depending on the income level.

Table 174 | Scenarios with Different Travel Distances by HSR for Users' SP Survey

Travel Distance	Survey Target	Scenario	In-vehicle Travel Time	Fare
Longer than 300km	Yangon-Mandalay travellers	1	150 min.	35,000 Kyat
		2	150 min.	50,000 kyat
		3	150 min.	65,000 kyat
		4	240 min.	35,000 kyat
		5	240 min.	50,000 kyat
		6	240 min.	65,000 kyat
		7	330 min.	35,000 kyat
		8	330 min.	50,000 kyat
		9	330 min.	65,000 kyat
300km or less	Yangon-Taungoo travellers	1	60 min.	15,000 kyat
		2	60 min.	20,000 kyat
		3	60 min.	25,000 kyat
		4	110 min.	15,000 kyat
		5	110 min.	20,000 kyat
		6	110 min.	25,000 kyat
		7	160 min.	15,000 kyat
		8	160 min.	20,000 kyat
		9	160 min.	25,000 kyat

c) Mode Choice Model Development

- For the mode choice model, multinominal logit model has been applied to predict the quantity of modal transfer from the existing cars, buses, rails and airplanes to the HSR after its construction.

$$P_{ijk} = \frac{\exp(U_{ijk})}{\sum_k \exp(U_{ijk})}$$

Where, P_{ijk}: Probability of choosing mode k from origin I to destination j
U_{ijk}: Utility of mode k from origin I to destination j

$$U_{ijk} = \beta_0 + \beta_1 Cost_{ijk} + \beta_2 Time_{ijk}$$

Where, $Cost_{ijk}$: Total travel cost by mode k in a travel between zones I and j
$Time_{ijk}$: Total travel time by mode k in a travel between zones I and j
β_1, β_2: Parameters for each independent variable
β_0: Characterization factor of mode k

- To incorporate the users' SP survey results, the utility of the existing mode and the HSR associated with its introduction has been calculated by utilizing Limdep statistical program. As a result of the analysis by this program, has been analyzed to be 0.2241, and the parameters for each independent variable and the characterization constants for each mode have been calculated as follows:

Table 175 | Mode Choice Model Establishment Results

Item	Parameters		Constants			
	Time	Cost	Car	Bus	Rail	Air
Value	-0.00046	-0.00028	-0.288528	-0.40106	0.026695	-0.30853
p-value	0.0278	0	0.0034	0.0008	0.8218	0.0013

8) Myanmar HSR Demand Forecast Results

a) Basic Assumptions

① Setting of Fare Alternatives

- The per-km fares of each mode of transportation in Myanmar are as shown below. It has turned out that the fare of airplanes is about 23.99 times higher than that of the existing rails. It has been analyzed that the fare of existing rails is relatively low

Table 176 | Fares of Different Modes in Myanmar

(Unit: Kyat)

Category	Bus	Existing rail (upgraded rail)	Air
Per-km fare	29.8	8.2 (30)	196.68
Compared with the fare of rails	3.6 times	-	23.99 times

Note: The existing rail means the rail currently being operated, and the upgraded rail means the rail when the Yangon~Mandalay rail upgrade, currently under way, has been completed.

- In this study, to apply the fare of the HSR for the demand forecast, the level of HSR fare when compared with the fare of air and the level of HSR fare when compared with the fare of local conventional rails were used. In South Korea, when compared with the air fare, the HSR fare is about 70%. The air fare between Yangon and Mandalay was 122,000 Kyat (per-km fare: about 196.68 Kyat/km). When applying the HSR fare in Myanmar, it would be about 137.68 Kyat/km. In this study, to forecast the demand changes with the level of fare, the following scenarios have been set based on the ratio of the HSR fare against the air fare.

Table 177 | Per-km Fares of the Modes of Transportation in Myanmar

Alternative	Fare Calculation Method
1	140 Kyat/km (70% of the air fare in Myanmar)
2	100 Kyat/km (50% of the air fare in Myanmar)
3	60 Kyat/km (30% of the air fare in Myanmar)

② b. Setting of Economic Growth Alternatives

- In this study, to establish the future O/D, economic growth scenarios with annual average GDP growth rates were set, and the HSR demand for economic growth rates has been forecasted by applying different economic growth alternatives to the demand analysis.

Table 178 | Per-km Fares of the Modes in Myanmar

Alternative	Economic Growth Assumed
1	GDP growth 8.0%
2	GDP growth 7.2%
3	GDP growth 6.2%

b) Myanmar HSR Demand Forecast Results

• To forecast the Myanmar HSR demand, basic assumptions were set for each alternative. In the case of fare, 100 Kyat or 50% of the Myanmar air fare was applied. For headways, 10 min. was applied. For economic growth, the annual average GDP growth of 7.2% or the moderate-growth scenario was applied. By doing so, the yearly demand has been forecasted. As a result of forecasting the total demand of the HSR, it has turned out that the demand will be 42,883 trips/day in 2030 when the HSR is opened. In 2040, 2050, and 2060, the total demand has been forecasted to be 82,181 trips/day, 121,945 trips/day, and 153,279 trips/day, respectively, with an annual average growth of 4.34%, which implies that it will grow steadily.

Table 179 | HSR Demand Analysis Result

(Unit: Trips/day, %)

Year	2030	2040	2050	2060	Annual Avg. Growth
Demand	42,883	82,181	121,945	153,279	4.34%

• Boarding/Deboarding Passengers Forecast Results by Station

Table 180 | Boarding/Deboarding Passengers Analysis Results for 2030

(Unit: Trips/day)

Station	Yangon → Mandalay			Mandalay → Yangon			Total boarding	Total deboarding
	Boarding	Deboarding	Onboard	Boarding	Deboarding	Onboard		
Yangon	16,825	0	16,825	0	16,688	-1	16,825	16,688
Bago	2,471	5,230	14,066	5,087	2,155	16,687	7,558	7,385
Phyu	425	2,223	12,267	2,302	459	13,755	2,727	2,682
TaungOo	382	2,855	9,794	2,637	428	11,912	3,019	3,283
Naypyidaw	166	3,529	6,431	3,050	290	9,702	3,216	3,819
Thazi	587	384	6,634	477	564	6,942	1,064	948
Kyaukse	721	196	7,160	279	724	7,029	1,000	920
Mandalay	0	7,160	0	7,474	0	7,474	7,474	7,160
	21,577	21,577		21,306	21,307		42,883	42,884

Table 181 | Boarding/Deboarding Passengers Analysis Results for 2040

(Unit: Trips/day)

Station	Yangon → Mandalay			Mandalay → Yangon			Total boarding	Total deboarding
	Boarding	Deboarding	Onboard	Boarding	Deboarding	Onboard		
Yangon	32,822	0	32,822	0	32,651	0	32,822	32,651
Bago	3,072	8,614	27,280	8,566	2,901	32,651	11,638	11,515
Phyu	887	4,744	23,423	4,944	979	26,986	5,831	5,723
TaungOo	883	5,446	18,859	5,360	958	23,020	6,243	6,404
Naypyidaw	605	6,274	13,191	5,747	462	18,619	6,352	6,736
Thazi	1,141	993	13,339	997	1,037	13,334	2,138	2,030
Kyaukse	1,892	580	14,651	360	1,891	13,374	2,252	2,471
Mandalay	0	14,651	0	14,905	0	14,905	14,905	14,651
	41,302	41,302		40,879	40,879		82,181	82,181

Table 182 | Boarding/Deboarding Passengers Analysis Results for 2050

(Unit: Trips/day)

Station	Yangon → Mandalay			Mandalay → Yangon			Total boarding	Total deboarding
	Boarding	Deboarding	Onboard	Boarding	Deboarding	Onboard		
Yangon	49,126	0	49,126	0	48,588	0	49,126	48,588
Bago	4,261	11,454	41,932	11,309	3,908	48,588	15,570	15,362
Phyu	1,387	5,957	37,363	6,230	1,441	41,187	7,617	7,399
TaungOo	1,328	7,641	31,050	7,530	1,504	36,398	8,858	9,145
Naypyidaw	1,403	10,738	21,715	9,922	808	30,373	11,324	11,546
Thazi	1,744	938	22,521	1,037	1,992	21,259	2,781	2,931
Kyaukse	2,102	479	24,144	719	2,352	22,214	2,821	2,831
Mandalay	0	24,144	0	23,847	0	23,847	23,847	24,144
	61,352	61,352		60,593	60,593		121,945	121,945

Table 183 | Boarding/Deboarding Passengers Analysis Results for 2060

(Unit: Trips/day)

Station	Yangon → Mandalay			Mandalay → Yangon			Total boarding	Total deboarding
	Boarding	Deboarding	Onboard	Boarding	Deboarding	Onboard		
Yangon	61,062	0	61,062	0	60,392	0	61,062	60,392
Bago	5,564	14,963	51,664	14,624	5,045	60,392	20,188	20,008
Phyu	1,695	7,653	45,705	7,830	1,773	50,812	9,525	9,426
TaungOo	1,623	9,307	38,021	9,187	1,730	44,755	10,810	11,037
Naypyidaw	1,577	13,273	26,325	12,138	987	37,299	13,715	14,260
Thazi	2,023	1,281	27,067	1,268	2,459	26,148	3,291	3,740
Kyaukse	3,522	612	29,977	905	3,827	27,339	4,427	4,439
Mandalay	0	29,977	0	30,261	0	30,261	30,261	29,977
	77,066	77,066		76,213	76,213		153,279	153,279

c) HSR Demand Forecast Results by Alternative

- In this study, the HSR demand fluctuations have been analyzed with the alternatives of fare and of economic growth set in the basic assumptions.

d) HSR Demand Change Analysis by Fare Alternative

- Basic Setting
  - Economic growth rate: Moderate-growth scenario (Annual average GDP growth 7.2%)
  - Headway: 10 min.

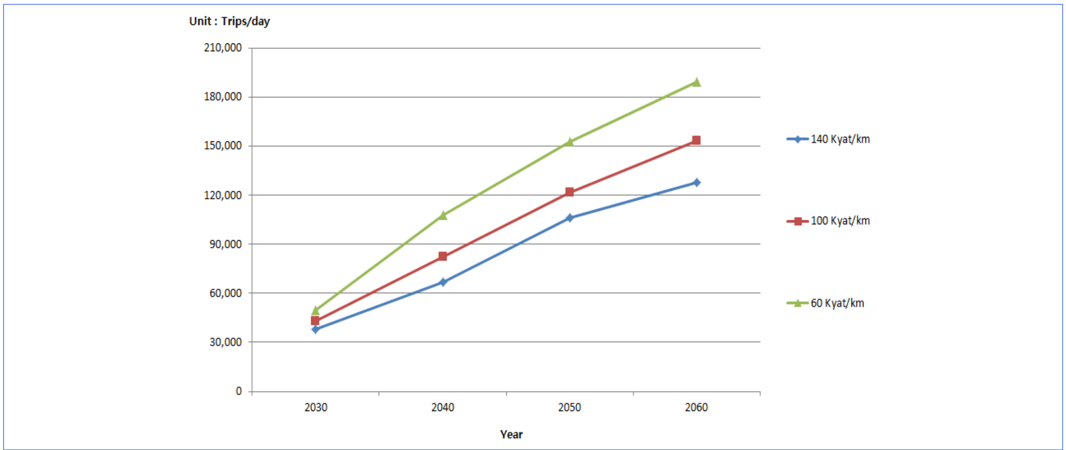
- Setting of Fare Alternatives
  - Alt. 1: 140 Kyat/km (70% of the air fare in Myanmar)
  - Alt. 2: 100 Kyat/km (50% of the air fare in Myanmar)
  - Alt. 3: 60 Kyat/km (30% of the air fare in Myanmar)

- Total Demand Analysis Results by Fare Alternative
  - With the alternative of 60 Kyat/km, the demand has been shown to be the highest while with that of 140 Kyat/km, the demand was the lowest. The annual average growth ranged from 4.13% to 4.55%.

Table 184 | HSR Demand Analysis Results by Fare Alternative

(Unit: Trips/day, %)

Year	2030	2040	2050	2060	Annual Avg. Growth
140 Kyat/km	37,898	67,073	106,093	127,691	4.13%
100 Kyat/km	42,883	82,181	121,945	153,279	4.34%
60 Kyat/km	49,717	108,047	153,001	189,158	4.55%



e) HSR Demand Fluctuation Analysis by Economic Growth Alternative

- Basic Setting
  - Fare: 100 Kyat/km
  - Headway: 10 min.

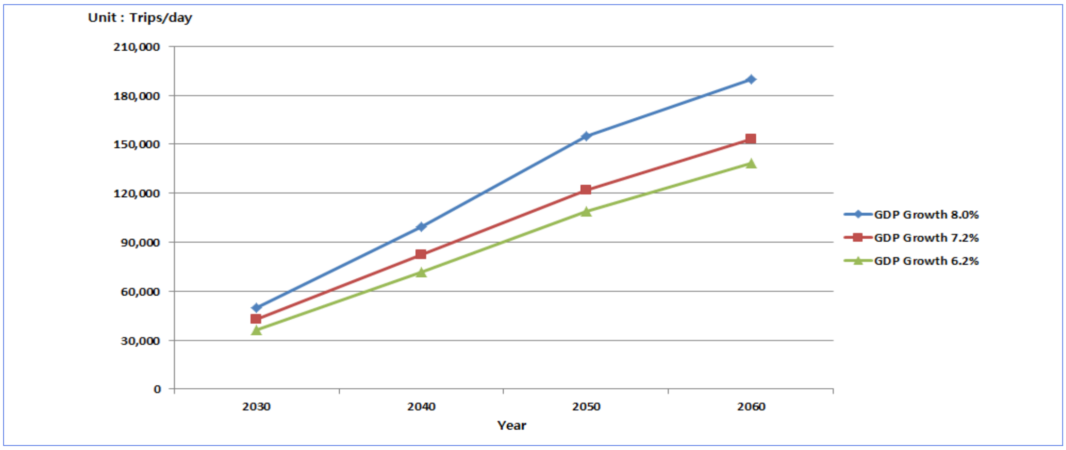
- Economic Growth Alternatives Setting
  - Alt. 1: High Growth (GDP growth 8.0%)
  - Alt. 2: Moderate Growth (GDP growth 7.2%)
  - Alt. 3: Low Growth (GDP growth 6.2%)

- Total Demand Analysis Result by Economic Growth Alternative
  - As a result of analyzing the total demand by economic growth alternative, in the case of high growth (GDP growth 8.0%), the demand was the highest and it increased with an annual average growth rate of 4.58%.

Table 185 | HSR Demand Analysis Result by Economic Growth Alternative

(Unit: Trips/day, %)

Year	2030	2040	2050	2060	Annual Avg. Growth
GDP Growth 8.0%	49,615	99,354	154,891	189,991	4.58%
GDP Growth 7.2%	42,883	82,181	121,945	153,279	4.34%
GDP Growth 6.2%	36,295	71,565	108,794	138,174	4.56%



11.3. Myanmar HSR-related Users' Survey Outcomes

- In this project, opinions were collected regarding the Yangon~Mandalay HSR construction through a survey of travellers in Myanmar. The survey targets included various travellers by rail, road and air.

11.3.1 Reasons Why They Do Not Prefer the HSR

- The biggest reason was expensive fare, which took up 83.5% of the whole targets. It is considered that since the existing rail fares are very low, the existing rail users have the feeling that the HSR fare level is very high. The first reason of high fare was followed by safety 7.0%, convenience 4.7% and accessibility 3.1%.

Table 186 | Reasons Why People Do Not Prefer the HSR

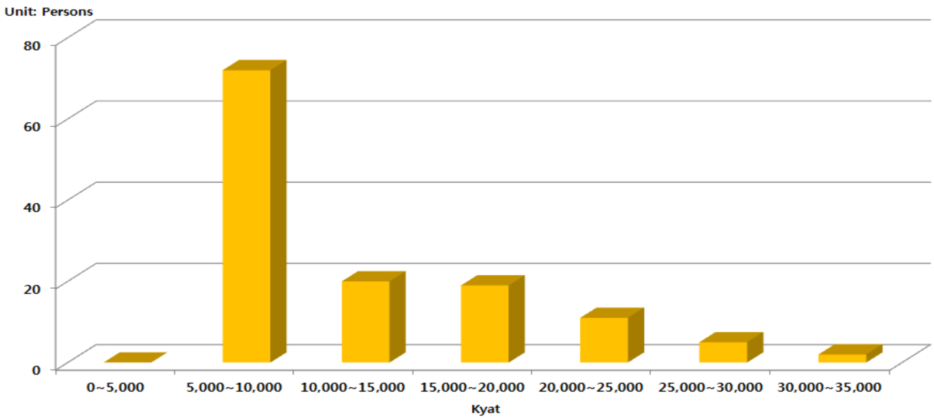
Reason	No. of Respondents	Ratio
Too high fare	110	85.30%
Low accessibility to stations	4	3.10%
Safety issues	9	7.00%
Inconvenient to use	6	4.70%
Other	0	0.00%
Total	129	

11.3.2. Proper Level of HSR Fare

Table 187 | Myanmar Travellers' Opinions about the Proper Level of HSR Fare

(Unit: Kyat, %)

Year	0~5,000	5,000 ~10,000	10,000 ~15,000	15,000 ~20,000	20,000 ~25,000	25,000 ~30,000	30,000 ~35,000
Samples	0	72	20	19	11	5	2
Ratio	0.00%	55.80%	15.50%	14.70%	8.50%	3.90%	1.60%



• When the in-vehicle time of the HSR in Myanmar is 2.5 hours, the results of analyzing proper fares to use it are as shown in the table below. The respondents, whose total number was 129, suggested 14,565 Kyat on average as the proper HSR fare (max. 35,000 Kyat and min. 5,000 Kyat). In the case of 100 Kyat per km, which had been set as one of the basic assumptions to forecast the HSR demand in Myanmar, if the fare for Yangon~Mandalay of 62,000 Kyat is taken into account, it is deemed to have a significant difference from the proper fare that the actual travellers who will use the HSR think.

11.3.3. Proper Timing for the HSR Construction

• As a result of the survey about the proper timing for the HSR construction in Myanmar, the opinion that it needs to be built as soon as possible takes up about 92.3%. Thus, it is considered that most Yangon~Mandalay travellers are positive about the HSR construction in Myanmar.

Table 188 | Myanmar Travellers' Opinions about the Proper Timing for the HSR Construction

Timing	No. of Respondents	Ratio
As soon as possible	405	92.3%
10 years later	27	6.2%
15 years later	7	1.6%
20 years later	0	0%
Total	439	100%

11.3.4. Opinions about the HSR

• The majority of the respondents about the HSR responded that with the construction of the HSR, the operating frequencies and punctuality should improve. It was followed by increased safety and lower levels of fare in order. Also, there were opinions that the HSR should be built by international standard and that it needed to be built as soon as possible. There was the opinion that the means of accessing the station needed to be provided.

Table 189 | Myanmar Travellers' Opinions about the HSR

Opinion	Samples	Ratio
The operating frequency and punctuality of the HSR should improve.	196	29.9%
Safety should improve.	136	20.8%
The price needs to be lowered.	127	19.4%
It is expected to influence service improvement (ticket purchase method, convenience, cleanness, etc.).	95	14.5%
The HSR needs to be built by international standard.	45	6.9%
It should be built as soon as possible.	25	3.8%
Accessibility to the stations is important, but it should be designed so that anybody can use it easily.	12	1.8%
The HSR track needs to be constructed by specialized engineers.	8	1.2%
The construction of the HSR should have positive impact on the economic development of Myanmar.	6	0.9%
PRs need to be made regarding the HSR construction & operation rules.	3	0.5%
The stations need to be upgraded (the stations are too small).	2	0.3%

Ⅴ. Conclusion & Policy Recommendations

- In this study, the HSR demand and construction cost in the case of the construction of a HSR in Myanmar have been estimated, and the economic and other conditions of the country have been reviewed. And the timing of its construction in Myanmar has been studied, and then policy directions have been presented. Incorporating the opinions of MR, the study scope has been limited to the suggestion of a plan to utilize a new HSR line.

- The construction cost of a 600 km HSR between Yangon and Mandalay is estimated at 20,363 Million USD or 28.1% of the GDP of Myanmar in 2017 (72,368 Million USD), and it amounts to 205% of the Myanmar Government's expenditure of 9,935 Million USD. Of course, the construction cost will be input over a period of about ten years, but when considering the present economic scale of the Government and its budget scale, it is deemed impossible to pursue the construction of the HSR for the whole Yangon~Mandalay route soon.

- If, however, it is taken into consideration that the economy of Myanmar recently grew at a high rate of 7~8% and that this growing trend is most likely to be continued in the future, it is deemed necessary to consider promoting the HSR project in Myanmar from a mid- and long-term perspective.

- At present, Myanmar's per-capita GDP is similar to that of Korea in the latter half of the 1970s, and in Korea, the construction of a HSR began to be pursued actively from the latter half of the 1980's, which was 10 years after that, starting with a feasibility study and basic planning. From the early 1990s, its construction was commenced and completed in early 2000s. Given this fact, if Myanmar continues to grow economically at such a high rate like today, it is deemed possible to pursue the construction of the HSR in full force beginning from the latter half of the 2020s.

- If the construction of the HSR is implemented actively in the latter half of the 2020s, when

Korea's experience is taken into account, its completion and opening is anticipated to be possible in the early and mid 2040s. The HSR demand forecast indicates that the daily HSR demand in the mid-2040s is expected to be about 100,000 to 130,000 people. For information, this is similar to the number of daily users of Gyeongbu HSR in Korea. To secure the HSR demand at that level, the following point can be considered as a key factor to be taken into account necessarily in pursuing the HSR construction in Myanmar: the assumed high economic growth rate of 7.2% should be continued up to the year 2040. In other words, if such a high economic growth is not maintained in the long term, it is deemed hard to secure the feasibility of the HSR construction.

- For Myanmar to make a success in the HSR construction in the future, it will be crucial to raise experts on HSR and other rail technologies and policies. To take a lead in the discussions about the HSR construction in the future and successfully implement the construction, it is absolutely necessary to secure experts on conventional and high-speed rails. The reason is that otherwise, it would be difficult to efficiently proceed with the construction and operation of the HSR, which will serve as the backbone transport network of the country.

- In the case of Korea, it did not have a sufficient number of experts on HSRs at the time of conceiving and constructing the HSR, but it had a lot of engineers with the expertise on conventional rails. Also, through feasibility studies and basic planning about the HSR construction and related international seminars, it could carry out the project successfully, particularly by employing Korea Transport Institute (KOTI), which could make decisions on the necessity to build a HSR and draw a public consensus on it. Korea could lead the HSR project to some extent by utilizing the engineers on conventional rails, but due to the shortage of the engineers on HSRs, it went through lots of trials and errors in the early stage of the HSR project, and such trials and errors resulted in the increase in the construction time and cost.

- Thus, it is deemed necessary to develop a system to bring up experts on railway technologies and policies. Accordingly, it is required to establish colleges and research institutes to raise such experts and to provide continuous opportunities of training for the personnel of the Myanmar Railways (MR). As a way of doing so, Myanmar may acquire HSR-related technologies from advanced countries with HSR systems through projects like the present KSP one. Myanmar needs to analyze what preparations those countries including South Korea had made for the introduction of HSRs, what kinds of trials and errors those countries went through, what policies and institutions they established, and what efforts they made for the HSR technology transfer. Through such analyses, Myanmar will be able to make positive preparations for its construction of the HSR.

- To reflect this aspect, this study has provided information on the trials and errors Korea experienced in the process of building the HSRs as well as its efforts to cope with the challenges they encountered and their improvement methods, and our major suggestions are as follows:

- For the HSR, eight stations were suggested with an average inter-station distance of 82.5 km, which is similar to 76 km or the average inter-station distance of the countries having operated HSRs. For information, Korea's average inter-station distance is about half of that of Myanmar. Average inter-station distances should be determined by closely examining the size of the stopping cities, transport demand and the speed of the HS trains and so as to be in keeping with the condition of the country concerned. Also, the cities selected for the stopping of the HS trains have been merely urbanized and are smaller in size than typical high-speed train stopping cities. As the cities in Myanmar are expected to be urbanized rapidly in the future, chances are that the cities may develop into a very different form than at present. Therefore, in the stage that the HSR is taken into serious consideration, the stopping stations need to be selected from a strategic viewpoint by incorporating the national land plans and urban plans along with the level of urban development.

- The locations of the HSR stations are another critical issue. The study team suggested utilizing the existing railway stations for some of the HSR stations and relocating some of them to the outskirts of the cities. Even in the case of Korea, the existing railway stations in major cities like Seoul, Busan, Daejeon and Daegu were upgraded and utilized for the HSR services while in small cities, new HSR stations were built at their outskirts. Utilizing the existing stations has the merit of better accessibility to the downtown, but a high cost is required for land appropriation around the stations. If the stations are built at the outskirts of the cities, it is possible to link them to the new town development plans and it is easy to appropriate the land, but there could be the problem of downtown accessibility. In Korea, there are some HSR stations built at the outskirts of the cities, which have so low accessibility to the downtown that the usage of the HSR is low. Therefore, if HSR stations are built at the outskirts of the cities, it is very important to establish a linked transport system such as metro systems, buses, taxis and cars in order to improve the accessibility to the downtowns.

- In utilizing the existing stations, the biggest problem is land appropriation. To solve this problem, it is deemed necessary to secure the railway sites for major stations such as Yangon station in advance. Generally, in order to utilize the existing stations for HSR services, a site of proper size is needed, but in the case of the existing Yangon Station, its length is only 620 m, which is too short for a HSR station. For information, although

Seoul Station is not a long station among the HSR stations in Korea, but its length is about twice that of Yangon Station. If the station is short, train operation will not be efficient. As it is deemed difficult to appropriate the land after the high-density development around Yangon Station, ways of minimizing the problems need to be developed when expanding major stations such as Yangon Station. It will be necessary to cope with the development of Yangon HSR Station in connection with the basic urban plans for major cities like Yangon.

- In addition, we described the environmental civil complaints and HSR safety issues that occurred in the process of the HSR construction in Korea, the trials and errors caused by the insufficient HSR technologies and the efforts made to overcome them. These data will be of great use for the construction of the HSR in Myanmar in the future. Particularly in Korea, the high-speed rolling stock was imported at the intial stage, but through the technology transfer from the HS R/S exporter, Korea successfully developed its own high-speed trains independently. When Myanmar introduces high-speed trains later, it will need to review the ways of technology transfer based on Korea's experiences.

- As mentioned earlier, it is deemed impossible due to the economic condition to implement the HSR construction for the whole planned route between Yangon and Mandalay any time soon, but it will be necessary to conduct a detailed feasibility study for the construction of a 68 km HSR between Yangon and Bago. As the construction of Hanthawardy International Airport is being pursued in Bago, the construction of the HSR needs to be examined in line with the present situation of promoting the airport construction. As cases of building HSRs linking an international airport and major cities, there are many of them in France, Germany, China, and so on.

- Also, in the viewpoint that the Yangon~Bago section may serve as a pilot track for the whole Yangon~Mandalay HSR route, the construction of the HSR in the section needs to be considered positively.

- If the technology and experience from the design, construction and operation of the Yangon~Bago (pilot section) HSR are utilized, the trials and errors in the construction of the HSR in the whole route will surely be reduced and a successful construction will be made. Also, if the pilot section HSR construction is linked to the new town development plans for the outskirts of Yangon and Bago, the effect of the project is expected to be maximized.

- To draw the investment priority order for railway construction and establish a mid- and long-term investment plan as well as the HSR construction in Myanmar, a master plan for the establishment of a national rail network in the country needs to be developed. To ensure the effectiveness of the master plan, a legal device that makes the establishment of a master plan compulsory needs to be created. In Korea, Railway Construction Act specifies that the plans for the establishment of a national rail network be established every five years. If the master plan for the establishment of a national rail network is prepared in Myanmar, the railway construction in the country is expected to be pursued more effectively and efficiently.

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Appendix 1

1. Questionnaire (Preference Survey)

Preference Survey as to the Introduction of a HSR to Myanmar (Type A)
(Yangon~Mandalay Travelers)

Hello?

We (Blue Nine Engineering & ….) are going to perform, at the request of Myanma Railways, this survey aiming to figure out preferences to use a high-speed rail, which will be a newly introduced mode of transportation between Yangon and Mandalay in the future, so we ask for your kind cooperation. The survey outcome will be utilized as important basic data in determining railway transportation policies in the future. We promise that the personal information and answers acquired through this survey will be summed up and be incorporated into the relevant study and then discarded. Thank you!

Interviewee's Information Survey

1. Did you travel today or have you travelled ever between Yangon and Mandalay?
① Yes ② No (the interview ends.)

2. What is your family's monthly average income? _______________ Kyat
① Above 1,500,000 Kyat ② 1,000,000~1,500,000 Kyat
③ 500,000~1,000,000 Kyat ④ Less than 500,000 Kyat

3. Which mode of transportation do you mainly use for the travel between Yangon and Mandalay?
① Car ② Inter-city Bus ③ Rail ④ Airplane

4. Currently, the existing Yangon~Mandalay railway line is under upgrade work. When the upgrade work is completed, it will take about 8 hours (In-Vehicle travel time) to travel from Yangon to Mandalay (one way), and the fare is expected to be about 19,000 Kyat. When the rail upgrading work is completed, which mode of transportation would you choose between the upgraded rail and the mode you chose in question no. 3.

① Existing mode (   )   ② Upgraded rail
(Please write the mode you chose in question no. 3.)

5. How old are you? ______________ years old.

6. Where do you live? _________ Region/State __________ Township

7. What is your gender?
① Male   ② Female

8. Do you have a car?
① Yes   ② No

Trip Information Survey

9. Please fill in one of the following cases (case 9-1~case 9-4). You are requested to provide travel information for the mode you have marked in question no. 3. For example, if you have selected '① Car' in question no. 3, please provide travel information about car by filling in the blank of question no. 9-1. If you have selected '② Inter-city Bus' in question no. 3, then please provide travel information about Inter-city Bus by filling in the blank of question no. 9-2. If you have selected '③ Rail' in question no. 3, then ……..

• In-vehicle travel time means the time taken during which you used the mode of transportation you have marked in question no. 3.

• Out-of-vehicle travel time means the sum of the time you spent until you got on the mode you have marked in question no. 3 and the time you spent until you reached your destination after you got off the mode. Out-of-vehicle travel time is sum of access time, waiting time, and egress time.

① Access time means the time taken from the origin of travel (home, office, etc) to transportation facility (parking lot, bus terminal, railway station, or airport) to use the transportation mode you have marked in question no. 3

② Waiting time means the waiting time for boarding the transportation mode you have marked in question no. 3 at bus terminal, railway station, or airport. Please do not consider waiting time for car users.

③ Egress Time means the time taken until you have reached the destination of travel (home, office, etc) after you have got off from the transportation mode you have marked in question no. 3 at bus terminal, railway station, or airport.

- Total travel time is defined as the total time taken for the traveler to reach the destination of travel from the origin of travel. Total travel time is the sum of in-vehicle travel time and out-of-Vehicle travel time.

- Total travel cost means total travel cost used by the traveler for the travel. Total travel cost includes not only the fare you paid for the use of the mode you have marked in question no. 3 but also other travel cost involved with the travel. The example of other travel cost could be taxi or bus fare to get to the bus terminal, railway station, or airport from the origin of travel or to get to the destination of travel from the bus terminal, railway station, or airport.

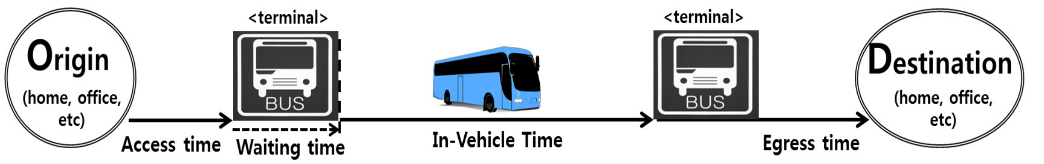
9-1. Car (In case, you have selected '① Car' in question no. 3)

In-Vehicle travel time	Out-of-Vehicle travel time		Total travel time
	① Access time	③ Egress time	
___________min	___________min	___________min	___________min

Fuel cost (A)	Toll (B)	Total travel cost (A+B)
________________Kyat	________________Kyat	________________Kyat

※ For example, if fuel efficiency is 10km/liter, fuel cost for the distance of 600km can be calculated as follows:
Fuel cost : Distance (600km) Fuel efficiency (10km/liter) Fuel price(750Kyat/liter) = 45,000Kyat
Please note that the fuel cost will vary according to the fuel efficiency, travel distance and fuel price.

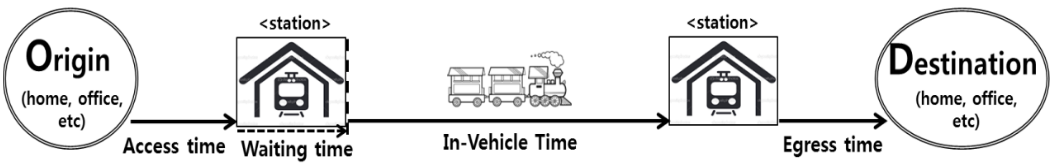
9-2. Inter-city Bus (In case, you have selected ‘② Inter-city Bus’ in question no. 3)



In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
________min	________min	________min	________min	________min

Fare for inter-city bus (A)	Other cost (Cost for bus, taxi, etc) (B)	Total travel cost (A+B)
________________Kyat	________________Kyat	________________Kyat

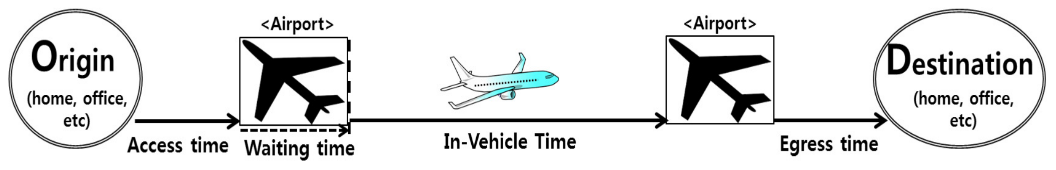
9-3. Rail (In case, you have selected ‘③ Rail’ in question no. 3)



In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	①Access time	②Waiting time	③Egress time	
________min	________min	________min	________min	________min

Fare for rail (A)	Other cost (Cost for bus, taxi, etc) (B)	Total travel cost (A+B)
________________Kyat	________________Kyat	________________Kyat

9-4. Airplane (In case, you have selected '④ Airplane' in question no. 3)



In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
________min	________min	________min	________min	________min

Fare for airplane (A)	Other cost (Cost for bus, taxi, etc) (B)	Total travel cost (A+B)
_________________Kyat	_________________Kyat	_________________Kyat

10. What was the purpose of your travel from Yangon to Mandalay or from Mandalay to Yangon?
   ① Going to/from work ② Business ③ Shopping/tourism
   ④ Visiting relatives ⑤ Other ( )

11. How often do you travel from Yangon to Mandalay or from Mandalay to Yangon?
   ① 5 times or more a week ② 2 to 4 times a week ③ Once a week
   ④ 1 to 3 times a month ⑤ 1 to 2 times a year ⑥ Other (times a year)

12. What is your main consideration when you choose a mode of transportation for a travel between Yangon and Mandalay?
   ① Travel time ② Cost ③ Comfort ④ Accessibility to the mode
   ⑤ Other ( )

Modal Preference Survey

What is a High-speed Rail (HSR)?

A high-speed rail (HSR), which is a type of passenger rail, is a new mode of transportation that provides faster rail services than existing conventional rolling stock. A high-speed rail can run at a maximum speed of 300 km/h or above. If this high-speed rail is constructed, it is expected to take about 2.5 hours from Yangon to Mandalay (about 7 to 8 hours by car and about 14 to 24 hours by existing rail). In the high-speed train, seats will be designated and reserved, and passengers can buy some snacks and drinks and use toilets on the train. A representative example of a HSR is the KTX of South Korea. Please refer to the pictures below and kindly answer the questions below.

13. The following table shows scenarios based on travel time and cost of a high-speed rail (HSR) when the new mode of transportation HSR is constructed. Please compare the mode you chose in question no. 4 under each scenario with the high-speed rail, and choose the mode you prefer (Please assume that The HSR station is located at the same location as the existing Yangon railway station and Mandalay railway station). Please also note that fare for the HSR does not include costs (for bus, taxi, etc) to reach the high speed railway station from the origin of travel or to reach the destination of travel from the high speed railway station. When you choose your preferring mode of transportation, please consider total cost and total travel time.

• In Vehicle travel time means the time taken during while you use HSR.

• Out of Vehicle travel time means the sum of the time you spent until you got on the HSR and the time you spent until you reached your destination after you got off the HSR. Out-of-vehicle travel time is sum of access time, waiting time, and egress time.

① Access time means the time taken from the origin of travel (home, office, etc) to railway station to use the HSR.
② Waiting time means the waiting time for boarding the HSR at railway station. We assume that waiting time for the HSR is 20 minutes.
③ Egress Time means the time taken until you have reached the destination of travel (home, office, etc) after you have got off from the HSR at railway station.

• Total travel time is defined as the total time taken for the traveler to reach the destination of travel from the origin of travel. Total travel time is the sum of in-vehicle travel time and out-of-Vehicle travel time.

Scenario 1.

In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
150 min	________min	20 min	________min	________min

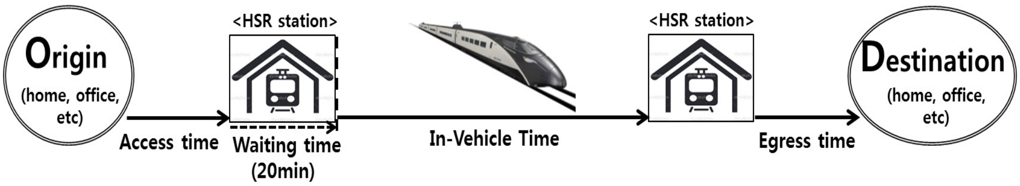
HSR fare : 35,000 Kyat

Q. Considering the above conditions, please choose your preferring mode (please mark on the number)

1. HSR (High-speed Rail)

2. The mode you have chosen in question no. 4 (   ) *please fill in the blank

Scenario 2.



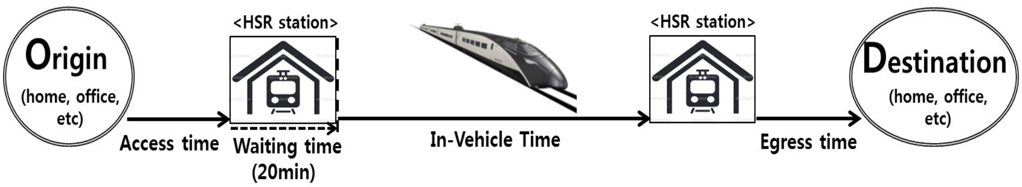
In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
150 min	________min	20 min	________min	_______min
HSR fare : 65,000 Kyat				

Q. Considering the above conditions, please choose your preferring mode (please mark on the number)

1. HSR (High-speed Rail)

2. The mode you chose in question no. 4 (   ) *please fill in the blank

Scenario 3.



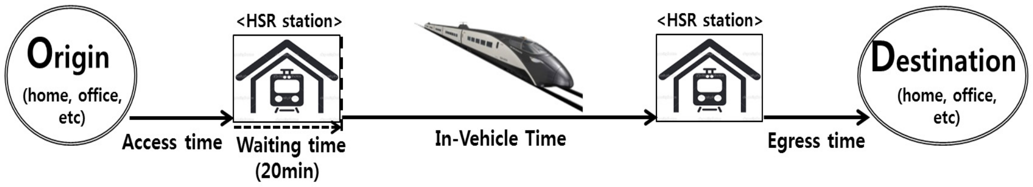
In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
225 min	______min	20 min	______min	______min
HSR fare : 50,000 Kyat				

Q. Considering the above conditions, please choose your preferring mode (please mark on the number)

1. HSR (High-speed Rail)

2. The mode you chose in question no. 4 (   ) *please fill in the blank

Scenario 4.



In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
300 min	______min	20 min	______min	______min

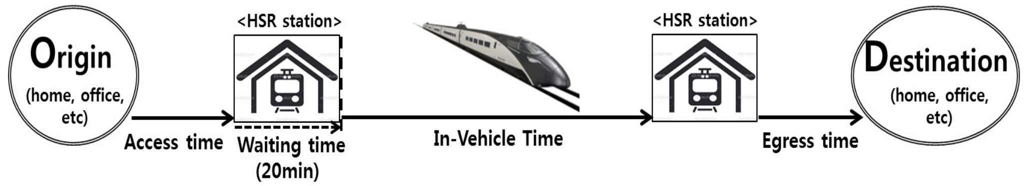
HSR fare : 35,000 Kyat

Q. Considering the above conditions, please choose your preferring mode (please mark on the number)

1. HSR (High-speed Rail)

2. The mode you chose in question no. 4 (   ) *please fill in the blank

Scenario 5.



In-Vehicle travel time	Out-of-Vehicle travel time			Total travel time
	① Access time	② Waiting time	③ Egress time	
300 min	______min	20 min	______min	______min
HSR fare : 65,000 Kyat				

Q. Considering the above conditions, please choose your preferring mode (please mark on the number)

1. HSR (High-speed Rail)

2. The mode you chose in question no. 4 (   ) *please fill in the blank

14. Why is it that you did not choose the HSR as your preferred mode in question no. 13?
 ① Because the fare is too high
 ② Because the accessibility of the station is not good enough
 ③ Because it does not seem to be safe
 ④ Because it does not seem to be convenient to use ⑤ Other ( )

15. Assuming that the in-vehicle travel time of the HSR is 2.5 hours, how much fare would you pay to use the HSR? (This question is applicable only to those who did not choose the HSR as their preferred mode in question no. 13.)
 __________Kyat

16. In which area do you think the HSR needs to stop when it is constructed?
 __________ Region/State __________ Township

17. Do you think the construction of the HSR (High Speed Railway) is necessary? If so, when do you think the construction should begin? (High speed railway will contribute to dramatically decrease travel time between areas in Myanmar. For example, if HSR is constructed, then it will take only about 2 hours and 30 minutes from Yangon to

Mandalay. Also, HSR is now being operated successfully in several countries such as Korea, China, Japan, France, Germany, and Spain. HSR is safe despite its high speed. Improved accessibility by HSR introduction is expected to contribute to attract more tourists and facilitate economic activities in Myanmar. However, it is costly to use HSR because it is expected to cost about 50,000 Kyats from Yangon to Mandalay or from Mandalay to Yangon. Further it would cost high construction cost of around 18 trillion Kyats. Please note that GDP of Myanmar in 2013 is approximately 51 trillion Kyats. It will take around 10 years for the construction of HSR, which means that high speed train could be serviced 10 years later even though Myanmar begin to construct HSR this year)

① As soon as possible ② 10 years later ③ 15 years later ④ 20 years later
⑤ Not necessary

18. If you answered that the project was not necessary, what was the reason?

19. Should you have any opinions or proposals about the HSR, please write them down

Name		Tel.		Survey Date & Time	Month__________ Day_________ Time_________

Thank you very much for completing this survey!

Appendix 2

1. Capacity Building Workshop

1.1. Overview

- To transfer to the officials of MR the knowledge that can be utilized for the railway construction and operation in Myanmar by enhancing the understanding of South Korea's experiences in the construction and operation of HSRs and quasi-high speed rails and their effects, a training program was provided for the policy enforcement personnel of Myanmar in Haemoo Hall of KRRI from Monday, 29 May 2017 to Saturday, 3 June 2017.

- This training was provided through lectures and site visits, which included visits to Hyundai Rotem Changwon Factory, Daegwallyong Tunnel along Wongang Line being constructed by KRNA, and Goyang HSR R/S Maintenance Shop of KORAIL.

Nationality	Organization	Name	Position
Mynamar	Myanmar Railways	Aung Win	General Manager (Technical&Admin)
	Myanmar Railways	Aung Myint Hlaing	General Manager (Commercial)
	Myanmar Railways	Aung Zay Myint	Deputy General Manager (Mechanical)
	Myanmar Railways	Maung Maung Thwin	General Manager (Civil)
	Myanmar Railways	Thet Soe	Assistant General Manager (Operating)

- Also, the visitors had a time to look around the test equipment in full scale and hear the explanation about it in KRRI, experiencing Korean culture and riding the mag-lev train in Incheon International Airport and a KTX train to move to Hyundai Rotem, which was in line with the purposes of the training.

- The line-up of the policy enforcement personnel of MR who participated in this training program is as shown in the table below.

1.2. Training Participants' Itinerary

- The training program was implemented as follows:

Date	Time	Activity	Remarks
5/29 (Mon)	07:50	Move (Yangon → Incheon)	KE472
	10:20~11:30	Rest & introduction of the training program	Team Leader Hak-Lae Noh
	11:30~13:30	Lunch	
	13:30~15:30	Introduction of KRRI (PPT & video) Test equipment tour	Team Leader Tae-Wook Kim
	15:30~17:30	Korea's signaling system (HS train control system)	President Yoo-Ho Kim
	17:30~19:30	Welcoming dinner	
5/30 (Tue)	08:30~09:20	Move	
	09:30~11:30	Introduction of Korea (Korean culture & language)	Lecturer Nam-Hyung Kim
	11:30~13:30	Lunch	
	13:30~15:30	Case studies on Gyeongbu HSR construction & operation (development and impact of Gyeongbu HSR)	Dr. Joon Lee
	15:30~17:30	Development and effect of HSR system (high-speed train technology)	Dr. Chang-Seong Jeon
	17:30~19:00	Dinner	
5/31 (Wed)	08:00~13:00	Move to Hyundai Rotem Changwon Factory	
	13:00~14:30	Introduction of Hyundai Rotem (PPT) HSR & conventional rail production site tour	Hyundai Rotem Manager Hyung-deok Kim

Date	Time	Activity	Remarks
	14:30~15:00	Move to Changwon Jongang Station	
	15:00~18:00	Move to hotel	
	18:00~19:00	Dinner	
6/1 (Thu)	08:00~10:30	Move to the Wongang Line construction site	
	10:30~12:00	Introduction of site work progress Site tour & technology explanation	KRNA Manager Hae-Ryong Jung
	12:00~13:00	Lunch	
	13:00~16:00	- Move to Capital-region HS R/S Management Group (in Goyang)	
	16:00~17:00	Introduction of HS R/S operation & maintenance status Maintenance shop tour	KRNA Senior Manager Sae-Deok Jang
	17:00~18:00	Move & dinner	
6/2 (Fri)	08:30~09:20	Move	
	09:30~11:30	Interim presentation	KOTI Dr. Jin-Su Moon
	11:30~13:00	Lunch	
	13:00~22:00	Korean culture experience and dinner	Seoul
6/3 (Mon)	10:00~12:30	Korean culture experience	DMZ
	12:30~15:30	Move to airport & maglev ride	Incheon International Airport
	18:45~	Leave South Korea (Incheon → Yangon)	KE471

1.3. Details of the Capacity Building Workshop

1.3.1. Lectures

1) A. HSR Train Control System

- Date & Time: Monday, 28 May 2017, 15:30~17:30
- Venue: International Conference Room (“Haemoo Hall”), KRRI
- Lecturer: President Yu-Ho Kim, 주식회사 에이알텍

- Subject: Korea’s Signaling System
- Major Contents
  - (Necessity) The equipment is required that can ensure the life safety and efficient communication with the train driver so that no accident may occur due to human errors in train operation.
  - Major countries that developed signaling systems
  - Importance of signaling in a high-speed train
    - Korea’s development of signaling systems
    - Reasons why train control system corresponds to the brain of a railway
    - Problems caused by high-speed operation
  - Centralized train control center
  - Monitoring & controlling the trains in all block sections
  - Operation scheduling, supervision of signaling systems and automatic route setting
    - Component systems of the center
    - Functions and roles of each component
  - Automatic Train Control
    - Inter-connectivity between onboard and wayside signaling systems
    - Signal transmission method and roles of track circuit devices
  - Interlocking eXchange Logic
    - IXL system configuration
    - IXL system operation method
  - Safety devices
    - The high-speed operation of trains increases the necessity of safety assurance.
    - Types of detectors and detecting methods in the event of various faults: obstacles, dragging, rail
      temperature, tunnel alarm system, earthquake detection, etc.

2) A Brief Overview of the Republic of Korea

- Date & Time: Tuesday, 29 May 2017, 09:30~11:30
- Venue: International Conference Room in KRRI (“Haemoo Hall”)
- Lecturer: Mr. Nam-Hyung Kim of Gyeonghak Education
- Subject: Introduction of Korea (Korean culture and language)
- Major contents
  - Introduction of Korean letters
    - Principles and combination of consonants and vowels
    - Pronunciation positions & sounds
    - Origin of the language
  - Recent Korean culture

- Korea being transformed into a multi-ethnic society
- Introduction of Korean culture being melted into the world
- Korea's major industries such as shipbuilding, automobiles and semi-conductors, and Korea's development situation
- Traditional and modern wedding ceremonies and the society being transformed into multi-nationality

- Introduction and practice of greetings & dialogue techniques

3) Development & Impact of Korean HSR

- Date & Time: Tuesday, 29 May 2017, 13:30~15:30
- Venue: International Conference Room in KRRI ("Haemoo Hall")
- Lecturer: Dr. Joon Lee of Green Transport & Logistics System Engineering Institute in KRRI
- Subject: Case studies of Gyeongbu HSR construction & operation
- Major contents
  - Overview of Korea's rail network
    - Carrying distance and capacities of subways and rails
    - Korea's rail development history by phase (1899 to present)
  - Conversion into HSRs
    - KTX project history
    - History of Gyeongbu Line Phases 1 & 2 and Honam Line
    - KTX technology transfer & difficulties and efforts in independent technology development
    - Suggestions of the best method to stand alone in HSR technology
    - Benefits from KTX vehicle development
  - Effect of Korean-style high-speed rails
    - Increase in the carrying capacities between Seoul and Busan
    - Travel time reduction due to the operation of high-speed rails
    - Socio-economic effect: balanced regional development, increased leisure time and technological improvement
  - Investment & planning policies
    - Necessity to balance with road transport
    - Importance of the policy change into rails
    - Korea's rail plan for 2020 and the implementation process of the transportation plan
  - Case studies on Korea's major success factors
    - Government leadership, partnership, gradual knowledge transfer and focus on capability improvement
    - Recommendations on the successful development of high-speed rail technology

4) The impacts of High-Speed Rail: Technologies for high-speed trains

- Date & Time: Tuesday, 29 May 2017, 15:30~17:30
- Venue: International Conference Room in KRRI ("Haemoo Hall")
- Lecturer: Dr. Chang-Seong Jeon, HSR Research Div. in KRRI
- Subject: Development and effect of HSR systems
- Major contents
  - High-speed trains around the world
    - Present condition and plan of high-speed trains and tracks
    - Countries' high-speed train user increase trend and ratios
  - Technologies required for high-speed rolling stock
    - Comparison of the features of high-speed rolling stock and types of train
      : Centralized power vs. distributed power; articulated bogies vs. normal bogies; tilting vehicles; and trains on variable track gauges
    - Major equipment and technologies for the speed-up of vehicles
      : High-speed bogies, current collectors, materials of car bodies, contact between wheel and rail, aerodynamic features, braking and electric power
  - Technologies for speed-up: aerodynamic technology, wheel/rail contact technology, dynamics of vehicles, braking, power collecting capacities and power transfer, and infrastructure such as roadbed and tunnels
  - Korea's high-speed tracks
    - Korea's high-speed train service increase patterns
    - The future of Korea's rail transportation associated with the increase in green public transportation
    - Korea's HSR development history and technology transfer
    - Technical configuration of HEMU 430

1.3.2. Visits to Other Companies

1) Introduction of KRRI & Test Equipment Tour

- Date & Time: Monday, 28 May 2017, 13:30~15:30
- Venue: International Conference Room ("Haemoo Hall"), Test Building Nos. 3 & 4
- Lecturer: Team Leader Tae-Wook Kim of Global Marketing Dept. in KRRI
- Detailed schedule

Time	Activity	Remarks
13:30~14:30	Introduction of KRRI	
14:30~15:30	Test equipment tour (civil and trackwork)	Bldg. Nos. 3 & 4

• Major contents
  - Visit to an integrated performance test system for full-scale rail structures and multi-axial fatigue test equipment for rail fastening

2) Visit to Hyundai Rotem sss

• Date & Time: Wednesday, 31 May 2017, 13:00~14:30
• Venue: Hyundai Rotem Changwon Factory
• Major contents
  - Introduction of Hyundai Rotem and presentation about its overseas projects
  - Visits to the rolling stock factory and work sites and technological explanation
    ‣ The process of welding steel plates in a car body plant and that of making the frame for rolling stock
    ‣ The process of special welding for the car bodies with aluminum, stainless steel and mild car (steel)
    ‣ Correction process, restoring process and painting process, and related technology explanation
    ‣ car connection process in the assembly factory
  - Q&A's about the processes

3) Visit to Korea Rail Network Authority (KRNA)

• Date & Time: Thursday, 1 June 2017, 10:30~12:00
• Venue: Wongang Line construction site (Daegwallyung section)
• Major contents
  - Introduction of Wongang Line & watching of a video about the construction technologies
  - Daegwallyung Tunnel inside tour
  - Q&A's about tunnel construction technologies

4) Visit to KORAIL

• Date & Time: Thursday, 1 June 2017, 16:00~17:00
• Venue: Capital-regional HS R/S Management Group in Goyang
• Major contents
  - A video of introducing Goyang HS R/S Depot
  - Explanation about high-speed vehicle maintenance methods and standard, vehicle service life, and so on
  - Tour of high-speed vehicle light maintenance facilities

5) Maglev Train Ride

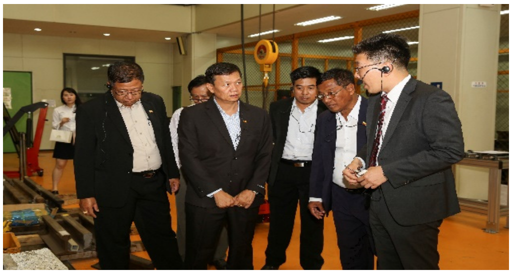
- Date & Time: Saturday, 3 June 2017, 15:15~15:30
- Route: Yongyu Station to Incheon International Airport
- Major contents
  - Riding the commercial maglev train developed for the first time in Korea and for the second time in the world
  - Explanation about major items such as service distances and scheduled speeds

6) Cultural Experience

- Date & Time: Saturday, 3 June 2017, 10:00~12:30
- Venue: Civilians access control areas in DMZ (De-Militarized Zone) (The 3rd Tunnel, etc.)
- Major contents
  - Watching a video about the security of Korean Peninsula
  - Explanation about Korean War & the current security of the peninsula
  - Visit to Mt. Dora station and Mt. Dora observatory

1.3.3. Related Photos

Lecture on Korea’s signaling system



KRRI test equipment tour

Interim presentation

Lecture on Korean culture & language

Lecture on Gyeongbu HSR construction & operation

Lecture on HSR system development & effect

KTX ride

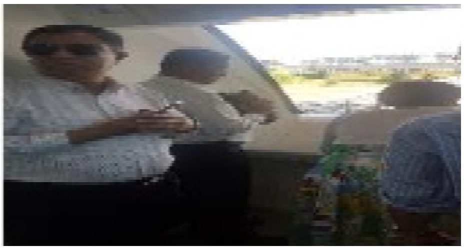
Hyundai Rotem tour

KRNA's Daegwallyung Tunnel tour

Visit to the Capital-region HS R/S Management Group of KORAIL

Korean culture experience

Visit to DMZ



Maglev train ride

Leaving Korea