20 Years of Korean High-Speed Rail History

20th

Ministry of Land, Infrastructure and Transport Korea National Railway Korea Railroad Corporation
SR Co.,Ltd Korea Railway Association Korea Railway Cultural Foundation

Writers

Yong-Sang Lee(Professor/Woosong University)

Chapter 1 **Chun-Hwan Kim**(Ex. Director General, Passenger Transport HQ, KORAIL)
Chapter 2 **Kee-Dong Kang**(Technical Advisor/Daegeon Engineering)
Byoung-Kuk Roh(President/Seohyun Engineering)
Chapter 3 **Dal-Ho Song**(Director/Ex. Korea Railroad Research Institute)
Chapter 4 **Chun-Hwan Kim**(Ex. Director General, Passenger Transport HQ, KORAIL)
Jeong-Rae Jung(Senior Vice President/Korea Railraod)
Chapter 5 **Jin-su Mun**(Senior Research Fellow/The Korea Transport Institute)
Kyung-Taik Kim(Associate Research Fellow/The Korea Transport Institute)
Chapter 6 **Yong-Sang Lee**(Professor/Woosong University)

English version

English version **Mi-Kyung Shin**(Professor/Woosong University)
Proofreader **Telisa Bryant**(Professor/Woosong University)

Interviewer

Yong-Sang Lee(Professor/Woosong University)

Inspection committee

Deog-Seong Oh(President/Woosong University)
Woo-Kung-Huh(Professor Emeritus/Seoul University)
GuenYul-Yang(Director/Ex. Korea National Railway Research)

Advisory committee

Eun-Sun Bae(Ex. Director/ Railroad Museum)
Abe-Seiji(Professor/Kansai University)

Editors

Ye-Kyeong Shin(Associate Professor/Namseoul University)
Min-Hye Hwang(Steering committee member/Korea Railway Culture Foundation)
So-Jeong Park(Asiistant Manager/Korea Railway Culture Foundation)
Soo-hyun Cho
Myoung-Sook Kim

Preface

Chairman of the Korea Railroad Cultural Foundation
Lee, Yong-sang

The year 2024 is a very significant year in the railway sector, marking the 20th anniversary of the opening of the high-speed railway on April 1. June 28 is the 130th anniversary of the Korean railroad, and August 15 is the 50th anniversary of the opening of the urban railway. These anniversaries have some significance, and we would like to mention why railroads need to grow further.

First, Korean railways, including high-speed and urban railways, are an essential national infrastructure used daily by 12 million people per day, or about 25% of the total population. Metropolitan railways and urban railways are a means of commuting to the workplace, and high-speed railways are a means of inter-regional transportation, contributing greatly to economic growth and balanced development. Also, the expansion and growth of the metropolitan area can be attributed to the railroad.

KTX, which marks its 20th anniversary on April 1, has nearly tripled the number of daily users from 72,000 at the time of opening to 229,000 in 2023, and the number of KTX regular ticket users has increased almost nine times, i.e., from 460,000 in 2004 to 4.04 million in 2024.

The number of lines and stops increased from 2 lines and 20 stations in 2004 to 8 lines and 69 stations in 2024. Starting with the operation of the Gyeongbu Line and Honam Line in 2004, the beneficiaries of the high-speed railway were the Gyeongjeon Line (Seoul∽Jinju) in 2010, Jeolla Line (Yongsan∽Expo) in 2011, 2015 Donghae Line (Seoul∽Pohang), 2017 Gangneung Line (Seoul ∽Gangneung), 2021 Jungang Line (Cheongnyangni∽Andong), and Jungbu Inland Line (Bubal ∽ Chungju) opened, increasing their influence.

Through this, KTX users surpassed 100 million users on April 21, 2007 and 1 billion users on August 31, 2023. This means that each of the 50 million Koreans used KTX 20 times. Currently, 240,000 people use the high-speed rail daily, and more than 90% buy it online, boasting a state-of-the-art operating system.

High-speed rail has greatly changed our country's economy and society. Compared to Japan and China, where high-speed railways have developed, we can say that the influence of high-speed rail is great despite our relatively small land area. In fact, in the case of Korea, the influence is concentrated in the metropolitan area. In the case of Gwangmyeong, Cheonan Asan, Daejeon, Daegu, and Busan, which are stopping stations, the area of influence is 70km centered on the stopping station, and most of the country is within the KTX's area of influence. Due to the impact of the high-speed railway, the Gyeongbu region, the Honam region, the Gangwon region, and the central inland region have become a one-day living zone, and the region is developing significantly around the station area.

Meanwhile, when the GTX-A line opens this year, the metropolitan area will be connected to a 30-minute living area. GTX-A can operate at speeds of up to 180 km/h, twice as fast as existing subways. The Suseo-Dongtan section currently takes about 80 minutes by public transportation, but when the line opens, the time will be drastically reduced to 19 minutes. When the entire section opens in 2025, it will be possible to travel in about 30 minutes from Paju, Gyeonggi-do, to Dongtan, making travel in the metropolitan area much easier. Passengers using high-speed rail can travel easily to their destination with connected transportation.

Second, in terms of global warming, railways are the means of transportation that emits the least carbon dioxide. In 2023, the average temperature rose by 1.4 degrees compared to before the Industrial Revolution. The temperature is expected to rise to 2.9 degrees in 2070, and as a result of this, many disasters, such as unprecedented floods and fires, are occurring on Earth, and the severity is also worsening.

So far, we have made efforts such as the Kyoto Protocol in 2008, the Paris Agreement on Climate Change in 2015, and the recent COP 28, but the reality is not that easy. Experts emphasize that the next few years will be the last time to save the Earth and that a future-oriented perspective considering greater benefits than costs is needed.

Recently, Hanson, a Columbia University professor who was the first to announce that climate change is coming, warned that global warming is progressing much faster than expected. In the 'Oxford Open Climate Change' academic journal, he stated that global temperatures could reach their limits within seven years. He argued that global temperatures would rise by more than 1.5°C above pre-industrial levels by the 2020s and by more than 2°C before 2050.

Accordingly, global warming is the most serious issue in the Sustainable Goals (SDGs). For Green Transformation (GX), an environmental tax must be imposed and paid as a subsidy for environmentally friendly means. From this point of view, the expansion of environmentally friendly rail transportation is very important. Recently, France has decided to abolish airlines within 2 hours and 30 minutes and replace them with high-speed rail by stopping cargo flights first.

In the case of Korea, it is now necessary to further expand the rail network centered on the high-speed rail network and make efforts to realize a carbon-neutral society.

In the midst of these environmental changes, the 20-year history of high-speed rail was written from the perspective of the universality and historicity of high-speed rail development.

First, it was described in terms of the continuity of Korea's railway development. We recognized aspects of development history such as improvement in speed, technological advancement, and improvement in capabilities. Although we initially relied on imports due to a lack of technology, we developed and operated our own G7 vehicle and Haemoo 430X ourselves, laying the foundation for local production of vehicles using these as models.

Second, the people who developed along with the planning process of high-speed rail were discovered, its process was analyzed in detail, and people's history was also mentioned.

In 1989, we learned of a person who significantly contributed to making difficult decisions when establishing the high-speed rail master plan. Minister of Transportation Kim Chang-Geun, who planned the high-speed rail at the time, was a person who put into practice a clear philosophy and will that Korea would enter the advanced country of the future only when high-speed rail and a new airport were built. It is Kim Chang-Geun, then Minister of Transportation, who was consistently mentioned through interviews by former Minister of Land, Infrastructure and Transport Jeong Jong-Hwan, former Vice Minister of Construction and Transportation Kim Se-Ho, former Korea Railroad Authority Chairman Kim Han-Young, and former Korea Transportation Research Institute Vice President Cha Dong-Deuk, who all contributed greatly to the development of our high-speed railway through policy.

When Korea planned and finalized the high-speed rail plan, only Japan and France were operating high-speed rail in the world, and Germany was under construction. Even under these circumstances, he was a person who predicted a future advanced country and prepared for a revolution in economic development and transportation.

The high-speed rail project, which created a new future for Korean transportation, was completed during his tenure. Minister Kim announced on March 18, 1989, that construction on the Gyeongbu high-speed railway would commence in August 1991 and that in 1998 the railway would operate to Busan in less than two hours. Based on this, a high-speed rail planning group was created, and the foundation for construction was laid. The minister's role in promoting the high-speed rail project at the time was necessary, and he was the person who persuaded President Roh Tae-Woo. Unfortunately, Minister Kim passed away on August 1, 1991.

Minister Kim Chang-Geun stressed that the future must be prepared, emphasizing: “High-speed rail is no longer a new technology as it has been 20 years since Japan began operating it. The world is trying to build it, and we must not fall behind, and we must secure technical capabilities. By the 21st century, we will be unified, and at that time, a train will have to run to Manchuria, but this will not be possible without a high-speed rail.” At that time, with such an atmosphere, the conviction of the Ministry of Transportation officials, high-speed rail planning officials, and the national interest in mind, the most prominent national project since Dangun was promoted.

At that time, the economic capacity to build a high-speed railway was not high, and Korea's per capita national income was just $252 in 1970, surpassing $1,000 in 1977 and $4,968 in 1988. According to data from the Bank of Korea at the time, per capita, national income (GNI) was 72nd out of 188 countries in the world in 1985 and 56th out of 211 countries in 1990.

Considering the financial situation at the time, deciding on a high-speed rail plan was not easy. This is because the general accounting budget in 1989 was 25 trillion won, but the project cost of the first revised plan was 10.74 trillion won, which was quite a large expense. Although there were some disagreements, each ministry cooperated and promoted the project to enter the developed country, and the driving force and political power at the time played a big role.

There are several episodes related to Minister Kim. In order to acquire advanced technology for introducing high-speed rail, he held an international symposium on his three European business trips. He thought that only by establishing an international human network could he overcome the difficulties arising from high-speed rail and that he put his life at stake to pursue it. According to records at the time, there were 631 attendees from October 16 to 22, 1989, and about 100 people from 10 foreign countries, including Japan, France, Germany, and the United States, attended. At the time of his inauguration, he had clear policy goals, such as announcing what he would pursue: high-speed rail and a new airport, and asking everyone to cooperate.

Third, the performance of high-speed rail was analyzed and presented in detail. After the opening of the Gyeongbu High-Speed Railway in April 2004, with the opening of the Honam High-Speed Railway and the Suseo-Pyeongtaek High-Speed Railway, the railway travel time on major transportation axes such as Seoul and Busan have decreased to about half compared to before the opening of the high-speed railway. Through such speed competitiveness and a relatively competitive fare policy, high-speed rail is establishing itself as a central means of transportation for medium- and long-distance travel in Korea. As of 2019, the high-speed rail shares between Seoul and Busan and Seoul and Gwangju were 62.1% and 49.5%, respectively, which were significantly higher than other means of transportation. In particular, air service between Seoul and Daegu was discontinued in 2007 due to the opening of the Gyeongbu High-Speed Railway. The distance used by high-speed rail per person increased 3.7 times from 114.96km to 429.17km during the same period. The area accessible to the high-speed rail within 60 minutes increased from 48.1% of the total land area at the beginning of the high-speed rail opening to 74.5% in 2018, greatly improving the accessibility of the high-speed rail across the country. As a result of reviewing and analyzing major research results and statistical data so far, high-speed rail is generally judged to have a positive impact on the local economy and social and cultural aspects. Professional baseball viewing products and local travel products using high-speed rail have appeared; delivery of local specialties via high-speed rail has become active, and high-speed rail has been shown to greatly contribute to revitalizing exchanges between people and goods, with the number of meetings held in high-speed rail stopping areas increasing.

Through the construction of high-speed rail, the development of station areas, including the development of residential areas near major stops and the construction of industrial and commercial facilities, is being actively promoted. Gwangmyeong Station and Cheonan-Asan Station are examples of successful residential land development projects near high-speed rail stops. In the case of Dongdaegu Station, a complex transfer center and large-scale commercial facilities were created using private capital. In addition, for most high-speed rail stations such as Daejeon Station, Singyeongju Station, Ulsan Station, Gimcheon-Gumi Station, and Busan Station, the construction of a complex transfer center, business and commercial facilities and cultural facilities is being promoted.

Fourth, the 20-year history of high-speed rail was mentioned from a future perspective. For Korea to achieve carbon neutrality, Article 32, Paragraph 5 of the Framework Act on Carbon requires that the government continue to: (1) expand investment in railways so that they can become the foundation of the national transportation network; (2) increase in public transportation such as buses, subways, and light rail; (3) set and manage mid- to long-term and step-by-step goals for railway transportation share, public transportation share, etc.

Based on this, the National Railroad Corporation has recently proposed a railroad share to reduce carbon emissions and social costs. Regarding passenger transport, the share should be 35% in 2030 and 40% in 2050, and cargo transport should achieve 15% in 2030 and 17% in 2050.

In order to achieve this, the role of railroads will need to change drastically. Rail traffic within the region must be integrated, expedited, connected, and automated. In the case of regional railroads, efforts must be made to increase speed, establish priority, establish hubs, and connect. Short-term strategies include operating a smart urban express railway, building a mobility station transfer platform, and developing a three-dimensional base centered on railway stations. Mid-term strategies include automation of digital-based railway operations, construction of national railway transportation main lines and feeder networks, and long-term innovation in future high-speed rail services.

Finally, we would like to make some suggestions related to the future. First, we must plan something memorable that preserves the past and promises the future. In the case of a museum that is a platform for preservation and succession, Uiwang is the choice, and it is time for a future science railway museum with a new future and science in it. Now, railways have become smart and advanced and have evolved to the point of using 5G, and advanced countries are on the verge of commercializing railways running at 600 km/h. In these times, museums will now become platforms for industry, experience, education, and fun.

Second, Korea is currently in a situation where no regular international railway-related conferences can be presented to the world. To celebrate the 20th anniversary of the opening of high-speed rail, it would be a good idea to hold an international conference tentatively named K-High-Speed Rail to share technological, industrial, and academic developments with the world every other year. Currently, countries such as Tanzania, Indonesia, and Paraguay, which are interested in high-speed rail and have active cooperation with Vietnam, should be invited to create a space for exchange and cooperation. Efforts are required to connect this with overseas expansion and expand the scope of exports in the current consulting, supervision, and urban rail vehicle fields.

With environmental analysis and STD strategies, it is essential to provide capital, technology transfer, and close mutual cooperation with countries with which Korea has a profound national relationship.

Lastly, we need to plan and participate in events so future generations can dream about railroads. Like the continental railway tour team conducted in 2015, it would be a good idea to divide the team into a European team, an Asian team, an African team, and a South American continental team this time, and conduct tours and promote our railway simultaneously.

Now is the time to establish a calm and practical plan as we welcome the first year of the new railway renaissance in 2024, and the 20 years of the Korean high-speed railway are meaningful when we look forward to the next 30 years.

CONTENTS

01

KTX: 20 Years of History

Completion of the First Stage of Gyeongbu High-speed Railway Construction

01 Completion of the First Stage of Gyeongbu High-speed Railway Construction

Section 1 Gyeongbu High-speed Railway Construction Policy Decision and Basic Plan Establishment

1. Gyeongbu High-speed Railway Construction Background and Promotion Policy Decision

Korea achieved high economic growth, reaching an average of 10% annually from the 1960s to the 1980s. In this process, transportation demand also increased rapidly. With the opening of the Gyeongbu Expressway in 1970, road traffic increased dramatically, but the demand for railway transportation continued to increase with economic growth. After the mid-1970s, fundamental measures were required to resolve transportation difficulties along the Gyeongbu axis, where approximately 70% of the population and gross national product were concentrated. As a result of several investigations, it was predicted that the Gyeongbu axis would reach saturation by the end of the 1980s, and new railway construction was proposed.

In the 1980s, the government conducted a feasibility study during the 5th Five-Year Economic and Social Development Plan (1982-1986) and decided on the transportation sector investment based on the results. As a result of requesting a feasibility study from four companies, including the Korea Research Institute for Human Settlements and the USA Louis Berger, from March 1983 to November 1984, the expansion of new transportation facilities was urgently needed because the railway and expressway along the Gyeongbu axis would reach their capacity limit by the early 1990s. Among the three alternatives, including the construction of a 4-lane expressway, the alternative of building a high-speed railway was presented as the most reasonable alternative due to its high efficiency. However, an investment in the transportation sector was not prioritized, and only the Gyeongbu High-speed Train technology investigation plan was reflected in the government's '6th Five-Year Economic and Social Development Plan (1987-1991)' established in 1986.

In the late 1980s, by hosting the Seoul Olympics, Korea began to globalize and set its sights on the level of advanced countries. Besides, relieving traffic congestion on roads due to the rapid increase in cars has emerged as an urgent project, so the high-speed railway construction project has gained momentum. In the 1987 presidential election, high-speed railway construction in response to inland transportation problems was presented as a pledge to solve national transportation problems, along with the construction of a new airport in response to increased demand for international airplanes and the construction of a new port in response to increased import and export cargo volume. After the Olympics, the Minister of Transportation Kim Chang-geun, who had a strong will to promote high-speed railway construction, took office. After active efforts, the Gyeongbu high-speed railway construction policy was decided upon with presidential approval in May 1989.

The objective of the high-speed railway construction plan at this time was to invest approximately 3.5 trillion won (government support) to build a double-track train in 1991 that could run at an average speed of more than 200 km/h over a distance of 380 km between Seoul and Busan. Construction would begin in August and be completed in July 1998 (a seven-year construction period). Also, the plan contained a detailed implementation plan, including a technology investigation. The construction policy for a new international airport under the jurisdiction of the Ministry of Transportation was also decided. In July 1989, the government launched the 'High-speed Train and New International Airport Construction Promotion Committee' and formed a research service group led by the Korea Transport Institute. Gyeongbu High-speed Train technology investigation has begun. The technology investigation, which was implemented in February 1991, was assigned tasks such as analysis of transportation demand and economic feasibility, review of alternatives for route/train station selection, basic design, and creation of a Request for Proposal (RFP) to select vehicle type.

2. Launch of Separate Organization Responsible for High-speed Railway Construction

According to Korean law, an organization dedicated to high-speed railway construction should be launched separately from the Korean National Railroad (a mainline railway operating agency). After completion, it should be operated by the Korean National Railroad. This gave great difficulty in managing the interface between construction and operations, unlike the urgent action of the Ministry of Transportation, whose objective was starting construction within President Roh Tae-Woo's Administration to ensure solid implementation by the large-scale project implementation practices at the time. It was only in December 1989 that the Korean National Railroad launched a dedicated working organization called the 'High-speed Train Planning Office' with a total of 54 people in 5 departments. The following year, the Korean National Railroad requested a large-scale increase beyond the number of personnel at the headquarters at the time due to the manpower required for high-speed railway construction; after review, the government dispatched several officials from related ministries to the Korean National Railroad T/F Team, which was expanded and reorganized into the 'High-speed Train Business Planning Team' in March 1991. In addition, a vice minister-level person was appointed as the head of the planning team, giving it the character of an organization virtually independent from the Korean National Railroad. Since it was difficult to effectively promote work by dispatching personnel for a short time, a regular organization was established. At the end of December 1991, the Korea High-Speed Rail Construction Corporation Act was enacted, and in March 1992, a corporation with a total of 379 employees was launched.

The High-Speed Rail Construction Corporation's separate launch marked the beginning of a European-style railway structural reform with separate upper and lower sections. Not only was the Korean National Railroad busy preparing for construction per the Korea Railroad Corporation Act enacted at the end of 1989, but it was also challenging to predict future conflict situations. At the time, the Gyeongbu high-speed railway was on the way to completion in 7 to 8 years. For a unit construction project of such a short duration, enacting laws on establishing and launching a regular organization, Corporation, was not to be taken lightly. It was simply explained that the Honam and Dongseo high-speed railway construction would continue following the Gyeongbu high-speed railway.

Later, in the late 1990s, the Honam High-Speed Railway project was delayed by about ten years, and the Dongseo High-speed Railway project was converted to a private investment method. Some High-Speed Rail Construction Corporation employees worried about their jobs after completing the Gyeongbu high-speed railway, attempting to operate the organization to ensure its survival. They were in conflict with the Korean National Railroad (the legal operator), becoming an obstacle to efficient operation preparations. This conflict was resolved only with the Railway Structural Reform Act in July 2003, which is based on the separation of upper and lower railway infrastructure and operations.

3. From establishing a Construction Basic Plan to Starting Construction

In October 1989, the ‘High-speed Railway International Symposium’ was held in Seoul and hosted by the Korea Transport Institute. For about a week, people could access in-depth information for the first time through presentations by high-speed railway experts from France, Germany, and Japan. In June 1990, when the technology investigation had progressed to some extent, the government announced the ‘Gyeongbu High-speed Railway Construction Basic Plan.’ The objective was to start construction in 1991 and complete the project in 1998 by investing a total investment of KRW 5.8462 trillion to build a high-speed railway that would run between Seoul and Busan in 101 minutes with a maximum design speed of 350 km/h, stopping at two stations. In the future, in addition to the Gyeongbu high-speed railway, the Honam High-speed railway and the East-West High-speed Railway will also be constructed to realize a half-day living area across the country.

As for the vehicle type, the most sharply debated technological issue in the National Assembly due to the claims of the science and technology community, instead of the ‘Maglev’ method, which is a next-generation method that has not yet been put into practical use, the ‘Wheel’ method was chosen, which was a proven technology at the time and was compatible with existing railways.

Lastly, regarding the issues surrounding the scope of the introduction of high-speed railway technology, considering the interconnectivity of the railway system, there was an alternative to introduce a total system that bundles technology in all fields. Another alternative was using our own technology for civil engineering, track, etc., and introducing only the core system, such as vehicle, tram line, and train control from abroad. The Core System method was chosen because it was judged to be advantageous for budget reduction and securing core technology.

From the second half of 1990 to the end of 1991, several domestic and foreign experts participated, led by the Korean Society of Civil Engineers. Here, high-speed railway design standards were established, and at the end of December 1991, high-speed railway construction rules were established to be used in detailed design. Looking at the main details, the maximum sales speed was set at 300 km/h, but the maximum design speed was set at 350 km/h in preparation for future speed improvement. The minimum radius of the curve was 7,000 m, the steepest slope was 25‰, the construction width was 14.0 m, the track center spacing was 5.0 m, the tunnel cross-sectional area was 107 ㎡, and the design load was based on the 'International Union of Railways'(UIC)-load standards. To summarize, we would compare Japan Shinkansen, France TGV, Germany ICE, Spain AVE, etc., and use the maximum to enable operation regardless of which vehicle type is decided. This approach seemed to have no problem at first glance, as it aims to build a world-class high-speed railway, but It was far from optimal, so construction costs have increased.

In June 1992, High-Speed Rail Construction Corporation announced the detailed route for the High-speed Railway. It was decided to build underground stations at Seoul, Daejeon, and Daegu, construct elevated stations at Cheonan, Gyeongju, and Busan stations to connect with general railways, and actively promote station influence area development. In response to complaints from Chungbuk residents, it would be excluded from future high-speed railway benefit areas. The detailed route was also partially changed to detour 4.3 km from the original and pass through Chungbuk Osong.

This shows the basic plan for high-speed rail construction in 1990 and the detailed route plan in 1992, which shows the perception of high-speed railway in Korea at the time. Developed foreign countries that introduced high-speed railways before Korea, such as Japan, France, and Germany, accepted high-speed railways as a major development of general railways to improve the competitiveness of rail transportation and expand transportation capacity. Therefore, when the high-speed train started operating, the general mainline train on the route was replaced by the high-speed train and stopped operating, leaving only local trains connecting the high-speed train stop station on the main line and the branch line.

However, in Korea, transportation experts who participated in the Gyeongbu high-speed railway technology investigation in 1989 recognized the High-speed Railway as a new means of transportation completely different from the general railway. For comparison, it is accepted as a new means of transportation that cannot be traveled on a general railway route, like the maglev railway currently under construction in Japan. Meanwhile, at the time, the Korean National Railroad's perception of high-speed railway was simply the introduction of a higher-grade train than the Saemaul-ho train, and all long-distance mainline trains along the Gyeongbu axis, such as Saemaul-ho and Mugunghwa, were replaced with high-speed trains. Therefore, it did not go as far as to increase the competitiveness of the railway. The perception of high-speed railways formed in this way had an impact not only at the construction planning stage but also at the operational stage. Rather than fully reorganizing the high-speed and general railways to complement each other, it led to inefficiency by running them together on the same route axis considering the user class.

High-Speed Rail Construction Corporation decided to begin construction first by selecting the approximately 57.2 km section between Daejeon and Cheonan as a test line section. It held a groundbreaking ceremony in the presence of the President on June 30, 1992.

Section 2 High-speed Vehicle Introduction Contract and Construction Project Progress in the mid-1990s

1. Conclusion of High-speed Vehicle Introduction Contract

A research service group led by the Korea Transport Institute was in charge of writing the Request for Proposal (RFP) to select the vehicle type. In a situation with no high-speed railway technology in Korea, it was not easy to write an RFP that included technology, price evaluation, and technology transfer details. In April 1991, the High-speed Train Project Planning Team was commissioned by USA Bechtel to supplement and review the draft RFP submitted by the research service group and confirm it. In August 1991, a Request for Proposal was sent to France, Germany, and Japan, major high-speed railway operating countries, and system selection work began. At the end of 1991, the High-speed Train Project planning team, based on the 'Proposal Evaluation Criteria' submitted by USA Bechtel, divided into four categories: cost, technology, businessability, and national interest (Technology Development), and domestic and foreign experts were selected, an evaluation team was formed, and the evaluation work began in February 1992.

After High-Speed Rail Construction Corporation took over the business and launched in August 1993, modifications to the technology proposal were requested six times, and modified proposals were received and evaluated. The reason why the proposal was requested to be revised so many times is that the content and price of the proposals were first submitted by foreign companies, such as Germany's Siemens, France's GEC-Alstom, and Japan's Mitsubishi, which participated in the bidding with high-speed railway vehicle production technology, fell far short of the level required by Korea. During the proposal evaluation process, we requested revisions several times based on competition among the three countries, resulting in content that was as advantageous as possible for us.

When the 6th RFP was sent, reflecting the first modified plan of the Gyeongbu high-speed railway construction project in June 1993, Japan's Shinkansen was excluded from the target based on the results of five evaluations. Sensing that the deadline was approaching, both France Alstom and Germany Siemens proposed much-improved content. The price was also far below the objective price, and the Corporation, which achieved satisfactory results in most evaluation items, decided to end the entire evaluation after the 6th proposal evaluation.

In August 1993, High-Speed Rail Construction Corporation selected France Alstom, which received the highest score in the comprehensive evaluation, as the preferred bidder. After negotiations, a key equipment supply contract was signed with the 'KoreaTGV Consortium (EUKORAIL),' mainly composed of France Alstom, in June 1994. The contract amount was 2,101.6 million dollars (equivalent to approximately 1.68 trillion won in Korean currency at the time). The overseas portion was 6 billion francs (about $1.031 billion), and the domestic amount was about $1.069 billion. The scope of supply included vehicles, tram lines, ATC, and train control devices. High-speed railway vehicles have 20 cars per train to accommodate more than 1,000 people. A total of 46 episodes are being delivered, including 12 produced in France and 34 produced domestically. Technology transfers, including expert training, were also included. The length of the high-speed vehicle has reached 400m, and the scale of platform train station buildings and vehicle depots has also become more extensive. Negotiations on introducing loans to raise funds are also underway. In August 1994, France signed a contract to introduce a loan worth $2.3 billion with France's Indosuez Bank as the lead manager.

2. Gyeongbu High-speed Railway Construction's 1st Revised Plan in June 1993

In March 1993, a project management service contract was signed with Bechtel, USA, to establish a project management system using advanced techniques. In addition, as a result of recalculating the investment cost and reanalyzing the construction period, the project cost was estimated to be KRW 12 trillion, approximately twice the original plan, and the construction period was expected to extend by three years; therefore, the basic plan for Gyeongbu high-speed railway has been revised. The revised plan announced in June 1993 took into account the national financial management of the newly launched civilian government, and instead of the underground New Line construction in the Siheung~Seoul~Susaek section, which requires many construction costs, the existing railway route will be improved and used, and NamSeoul Station (currently, Gwangmyeong Station) was newly established as Metropolitan Area No.2 station. It was decided to save 1.43 trillion won in costs through the ground construction of Daejeon, Daegu, and Busan Stations and change the bridge structure format (PC Box → PC Beam). Accordingly, the required budget was adjusted to KRW 10.74 trillion, and construction resources were determined to be 45% financial support (35% contribution, 10% loan) and 55% self-procurement. According to the utilization of existing lines in the Seoul City Center section and the grounding of the Daejeon and Daegu City Center passage sections, it was analyzed that the high-speed train operation time between Seoul and Busan would be 140 minutes, with two stops in between. The completion objective was delayed from August 1998 to May 2002. However, the goal for the Seoul-Daejeon section, where construction of the test line section began early, was to be completed by 1999 and open in 2000.

In the first modified plan, construction of the underground new line in downtown Seoul was postponed until after 2010. An obstacle to utilizing the existing railway route was that the track capacity of the Gyeongbu Line Seoul~Yeongdeungpo section needed to be more saturated. The track capacity was 122 (on a one-way basis). Still, only general trains, including 106 passenger trains such as Saemaeul, Rose of Sharon, and Pigeon, and 16 freight and parcel trains, were operating to the capacity limit.

Alternative suggestions are: the line capacity is increased to 157 through improvements such as adjusting the automatic blocking signal interval between Seoul and Siheung; The Cargo and parcel train change its starting and final station to Uiwang Station (Bugok Station at the time); General passenger trains reflect the transfer of demand to higher-class trains, but if half of them are distributed to Yongsan Station by limiting the number of passenger trains to 106, which is the existing number, the calculation was that 51 high-speed trains would be possible to reach Seoul Station. Considering the demand for high-speed railways in 2002, a total of 110 high-speed train operations are needed. The plan was to build a new NamSeoul Station at the end of the high-speed New Railway line and start 59 High-speed trains. NamSeoul Station, located in Gwangmyeong City, is difficult to access by public transportation, so a lot of investment was needed to improve accessibility.

3. Gyeongbu High-speed Rail Construction Project, which Suffered Hardships in the mid-1990s.

In September 1993, a High-Speed Railway Vehicle depot location was selected. Seoul Vehicle Depots is a site of approximately 387,000 pyeong in Gangmae-dong, Goyang City, 13.5km away from Seoul Station, and Busan Vehicle Depots is a site of roughly 130,000 pyeong at the first military supply depot in Danggam-dong, Busan City, 7.1km away from Busan Station. Incoming lines were also planned from the starting and final stations, Seoul Station and Busan Station, to both Vehicle Depositories.

The mid-1990s was a difficult time for the Gyeongbu high-speed railway construction project. Construction should have been promoted in earnest, along with progress in land acquisition. In the first modified plan of the Gyeongbu high-speed railway, the high-speed railway bridge type, which changed to PC Beam to reduce costs, was changed back to PC Box, which has excellent safety, as a result of dynamic analysis commissioned by a foreign expert. In June 1994, immediately after the contract to introduce France TGV was signed, for a comprehensive safety review, we commissioned SOFRARAIL, a subsidiary of SNCF (Société Nationale des Chemins de fer Français), to conduct detailed verification of the main types of bridges in the test line until June 1995. Based on this verification result, a domestic design company supplemented and modified the remaining bridges.

In April 1995, the construction plan for the Daejeon-Daegu downtown passage section, which had been revised to be above ground, was reversed to underground again due to opposition from residents who pointed out environmental damage such as noise and vibration and urban division. In mid-1995, a controversy arose when the Ministry of Culture, Sports and Tourism requested that the Hyeongsan River route passing through the Gyeongju section be changed to a suburban route, claiming it would damage cultural assets and the Namsan landscape. Ultimately, in June 1996, the Promotion Committee reviewed a new route for the Gyeongju section and decided to use the existing Gyeongbu Line Daegu-Busan section with improved electrification as a temporary replacement route in response to delays in the construction period. As a result of the review, the

Gyeongju section was changed to the Hwacheon-ri New Route in January 1997. In September 1995, safety issues were raised in the Sangri tunnel section adjacent to the abandoned mine shaft in Gyeonggi-do Hwaseong-gun. After conducting services to eliminate uncertainty, a route change policy was decided in October 1996. In March 1997, the detour route for the Sangri Tunnel section was confirmed.

In early 1996, during the construction of Pungse Bridge, the longest bridge in Korea, the construction period was delayed due to problems with the design of the bridge deck. Korea Train Express commissioned SYSTRA, a French railway engineering company, to prepare bridge upper part optimization design drawings and detailed construction drawings. Korea Train Express signed a contract with WJE, a global safety diagnosis company, to put an end to the controversy over poor construction. Safety inspections were conducted on structures constructed until 1996 (1st: August 1996 to January 1997, 2nd: August 1997 to January 1998). As a result of the inspection, most of the points pointed out were minor defects that did not cause structural safety problems. It was reported in the media as if it were a total mistake and received major criticism.

As these storms continued, the ‘High-Speed Rail Construction Planning Team’ was launched in the Ministry of Construction and Transportation in December 1996 to help promote the project at the government level. In particular, in April 1997, the 「High-Speed Rail Construction Promotion Act」, enacted as a special law for efficient project promotion, gave breathing room to promote various administrative procedures such as land purchase and local government consultation, which had been holding back. In the first half of 1997, under the leadership of the High-Speed Rail Construction planning team, a comprehensive restructuring of the construction period was undertaken by analyzing the process according to changes in the situation, and the construction project was finally on track in the second half of the same year when the construction process was confirmed.

4. Railway Facility Maintenance Project and Existing Line Electrification according to the Utilization of Existing Lines of High-speed Railway

After the spin-off of the High-Speed Rail Construction Corporation in 1992, it was mid-1994 when the Korean National Railroad again participated in the High-Speed Railway project. According to the first revision of the Gyeongbu high-speed railway construction basic plan in 1993, when it became necessary to adjust the function of existing railway facilities and relocate them, the High-Speed Rail Construction Corporation requested a consultation with the Korean National Railroad. Korean National Railroad and High-Speed Rail Construction Corporation commissioned an external professional agency for one year starting in November 1994. They implemented the ‘Gyeongbu high-speed railway Basic Plan' to utilize existing lines. According to the service results, in March 1996, a railway facility maintenance project agreement based on the use of existing lines of the Gyeongbu high-speed railway was signed with a total project cost of KRW 911.9 billion. High-Speed

Rail Construction Corporation decided to bear the project cost, and the Korean National Railroad took charge of implementation.

The main project contents are: Improvement of wiring and platforms at stations such as Seoul·Yongsan·Daejeon·Dongdaegu·Busan·Busanjin, etc.; Increasing track capacity between Seoul and Siheung for high-speed train operation; Double track train between Seoul and Susaek (Goyang); Double track between Sasang and Bujeon for distributed handling of general trains; Vehicle Depos, which interferes with high-speed railway construction; and, the project involved relocating cargo handling centers, etc., including Bugok Freight Center and Vehicle Depots construction, relocation of Daejeon locomotive office and passenger car office, and relocation of Busan passenger car office and freight car factory 2.

Meanwhile, Kim In-Ho, President of the Korean National Railroad, who had a strong will to improve the efficiency of the entire railway through railway structural reform and high-speed railway operation, at the end of 1994, led the working-level team and visited to look around the sites of Europe's advanced railways, such as SNCF (Société Nationale des Chemins de fer Français), which has developed and is operating TGV, and renewed awareness of high-speed railway. Immediately after the business trip, the ‘High-speed Railway Operation Preparation Group’ was launched as a task force organization to give strength.

In July 1995, the Korean National Railroad High-speed Railway Operation Preparation Group established the “High-speed Railway Operation Preparation Comprehensive Plan.” By connecting the high-speed railway line and the existing railway network according to the French TGV method, for the first time, a plan to expand the high-speed train service area by directly connecting high-speed trains was proposed. In this plan, the Korean National Railroad presented the basic direction for constructing a connection line between the high-speed railway, the existing railway network, and the existing line electrification project. Large-scale project costs were required to realize this, so the government's financing plan had to be supported. First, to raise awareness of the need, the Korean National Railroad began promoting public opinion by holding a seminar on effective operation plans for high-speed railways in the second half of 1995.

The opportunity to realize the plan to expand the high-speed railway beneficiary area came surprisingly quickly. From the second half of 1995 to early 1996, the government's SOC working group, which was embroiled in controversy over the Gyeongbu high-speed railway route via Gyeongju, expressed interest in the Korean National Railroad's plan. During the government's review process, in response to delays in the construction period due to changes in the high-speed route via Gyeongju, a policy was decided to utilize the existing Gyeongbu Line between Daegu and Busan by improving electrification as a temporary alternative route. The project to expand the area benefiting from high-speed railways by directly connecting high-speed trains to the existing railway network has taken its first step.

5. Railway Facility Maintenance Project Modification and the first Integrated Plan

In the second half of 1996, while the Korean National Railroad High-speed Railway Department was conducting an on-site investigation to improve the electrification of the Daegu~Busan section of the Gyeongbu Line, it was recognized that there was a significant problem with the Busan district facility improvement plan according to the results of the 「Gyeongbu high-speed railway's existing line utilization basic plan」 service. Korean National Railroad has developed an effective modification plan that will improve the efficiency of train operation and significantly reduce the cost of the High-Speed Rail Construction project. After consultation with High-Speed Rail Construction Corporation, a modified plan was finalized in December 1996.

Learning from this, the Korean National Railroad reviewed the basic plan for the Seoul district railway facility maintenance project in early 1997 and discovered that there was a serious problem in the wiring plan of Seoul Station and Yongsan Station, such as the train arrival and departure line group being designed so that the northbound trains and southbound trains intersect on a plane. Korean National Railroad has made efficient wiring changes, such as dividing Seoul Station's internal wiring into arrival and departure lines rather than dividing it into high-speed railway and general railway. The northbound trains' and southbound trains' intersection problems at Seoul Station and Yongsan Station were resolved. At the same time, as demand for high-speed railways increased, regular trains were gradually reduced to enable conversion to high-speed trains.

Seoul Station and Yongsan Station were distributed according to train class. Depending on the destination, south-east bound trains, such as Gyeongbu and Chungbuk, leave from Seoul Station and arrive at Seoul Station, while Southwest trains, such as Honam, Jeolla, and Janghang, leave from Seoul Station and arrive at Yongsan Station. For the first time, a passenger train operation plan that integrated high-speed railway and general railway was presented.

In particular, according to this revised plan, we were able to find an agreement and resolve the issue of the location of Seoul Central Station on the high-speed railway, which was being carried out as a joint research project by the Korea Transport Institute and the Seoul Development Institute after conflict with the Seoul Metropolitan Government. According to the modified plan, when constructing the Honam high-speed railway in the future, Yongsan Station would not only be used as the starting and terminal station but also when the Gyeongbu high-speed railway opens, the planned round-trip high-speed train between Seoul and Daejeon would be changed to run between Yongsan Station and Seodaejeon Station. High-speed trains would start and end at Yongsan Station, which Seoul City has claimed as the location of the central station for high-speed railway. The integrated train operation plan for high-speed railway and general railway passenger trains established then was reflected in the Gyeongbu high-speed Railway 2nd modified plan in 1998. The high-speed train round trip plan between Yongsan Station and Seodaejeon Station became the starting point for establishing the Honam Line Electrification Project plan, which would later run a high-speed train directly from Seodaejeon Station to Gwangju and Mokpo.

Section 3 Meaning of Gyeongbu High-speed Railway's 2nd Revised Plan and Contents of 1st Phase Project

1. Gyeongbu High-speed Railway's 2nd Revised Plan and its Meaning

Since October 1997, the Ministry of Construction and Transportation High-Speed Rail Construction planning team has held expert discussions and public hearings in order to prepare alternatives for changing the Gyeongbu High-Speed Railway's 2nd Project plan by readjusting the construction period and project cost to reflect changes in the situation. Regarding the Daejeon-Daegu downtown passage section, where the construction period was extended by three years and six months due to undergrounding, and regarding the Daegu-Busan section, where the construction period was extended by three years and six months due to the change in Gyeongju route, the alternative of opening the existing line first in July 2003 by utilizing electrification was analyzed to be the most economical among several options.

The process for changing the Gyeongbu high-speed railway project plan was delayed due to a close review due to the foreign exchange crisis at the end of 1997 and the first change of government between the ruling and opposition parties due to the presidential election. It was adjusted to minimize initial investment costs to overcome the economic crisis. The Gyeongbu high-speed railway's 2nd modified plan, confirmed in July 1998, was an alternative to phased construction. First, in the 1st phase, the Daejeon-Daegu downtown passage section and the Daegu-Busan section of the Seoul-Busan High-Speed Railway route were electrified and improved, opening in April 2004 (Seoul-Daejeon section in December 2003). The 2nd phase project, which involves constructing a new high-speed railway line in a section utilizing the existing line, was separated from the 1st phase project to minimize initial investment costs and was changed to construction to start in 2004 and complete in 2010.

According to the 2nd modified plan, the total extension between Seoul and Busan was 412km, and the total project cost was estimated at KRW 18.4358 trillion. The 1st phase project cost was KRW 12,737.7 billion, which was suppressed to not increase much from the total project cost scale of the first modified plan. The 2nd modified plan reflected the 'Integrated Train Operation Plan' established by the Korean National Railroad in 1997. When the 1st phase opens, the high-speed train between Seoul and Busan will take 160 minutes (116 to 122 minutes when the 2nd phase opens). If the number of high-speed trains is 116, making full use of the 46 trains contracted for introduction, it was judged that it could meet the forecast transportation demand in 2008 (196,469 people per day).

The 2nd modified plan not only advances the opening of the Gyeongbu high-speed railway by about three years but also constructs connection lines with the high-speed railway in several locations and electrifies and improves the existing Gyeongbu Line. Therefore, like the French railway, Korea could also organically integrate the high-speed railway route into the existing railway network, allowing the area to benefit from high-speed train service to expand. In addition, the construction plan for each stage provided an opportunity to reexamine the Daejeon-Daegu downtown transit section, which was converted underground, for efficient construction. Even if the high-speed railway route is underground, not only will the general railway remain above ground, but the construction of the high-speed railway underground train station will cause many problems. Therefore, the rational logic that it would be better for urban development to improve the railway area by grounding the high-speed railway along the general railway route gradually gained strength. In April 2004, with the opening of Gyeongbu high-speed railway's 1st phase, the experience of a high-speed train quietly gliding across the city section of the existing line prompted local public opinion to turn around, and Daejeon City and Daegu City agreed to implement grounding on the premise of maintenance of facilities around the railway. Groundbreaking was finally confirmed in July 2005.

2. Contents and Progress of Gyeongbu High-speed Railway's 1st Phase Project

The details of the 1st phase project cost of 12.7377 trillion won are as follows: the high-speed railway new line construction sector has a land area of 13.02 million ㎡ worth KRW 468.1 billion; the roadbed is 409.8km, worth KRW 4.3957 trillion; the track is 542.2km, worth KRW 516.5 billion; the building is 166,934㎡ of the train station and 41,365㎡ of other buildings, worth KRW 379.8 billion; 2.7101 trillion won for 46 vehicles; vehicle deposits amounted to KRW 697 billion in two locations in Seoul and Busan; electrical substations, transmission lines, etc. cost KRW 676.6 billion; telecommunications, including transmission facilities, telecommunication lines, and train wireless systems, amount to KRW 408.6 billion; signals such as ATC and interlocking devices amount to KRW 301.6 billion; Design cost of KRW 197.8 billion; supervision fee of 234.8 billion won; additional expenses of 42.5 billion won; PM project cost 157.1 billion won; 24.4 billion won was allocated for research/drawing standardization; Korean National Railroad execution division: KRW 645.8 billion for construction of alternative facilities (railway facility maintenance project) such as improvement of existing station premises according to the first modified plan; According to the 2nd modified plan, KRW 881.3 billion was allocated for the construction of electrification and connection lines between Daejeon-Daegu downtown section and Daegu-Busan. This project cost was managed without any further changes until opening in 2004.

The completion rate of the Gyeongbu high-speed railway's 1st phase construction project from its start in June 1992 to 1997 remained at around 15% due to various problems in the early stages of the project; however, it progressed by about 30% over the two years from 1998 to 1999, more than double the progress over the past five years, and achieved a completion rate of 44.3% at the end of December 1999.

3. Key Characteristics of Gyeongbu High-speed Railway's 1st Phase Project Infrastructure

(1) Roadbed

In the Gyeongbu High-speed Railway's 1st phase project, of the 408.5km between Seoul and Busan, the High-speed New Railway line consists of 223.6km, the connection between the high-speed railway line and the existing line is 15.0km at 4 locations, and the existing line utilization section is 169.9km. The High-speed New Railway Line, which has been straightened with a minimum radius of curve of 7,000 m, has 104 bridges and is 89.0km long (39.8% of the high-speed railway line extension); there are 51 tunnels spanning 77.2km (34.5% of the high-speed railway line extension); the earthwork section is only 57.4km (25.7% of the high-speed railway line extension). All sections of the high-speed railway line are three-dimensional with the road, so there are no level crossings for cars to cross. Not only did it fundamentally prevent railroad crossing collisions, but fences were installed on both sides of the track in the earthwork section to prevent the intrusion of people and animals, preventing the possibility of casualties.

Main roadbed structures are as follows: the Eoyeon Overpass Bridge in the Pyeongtaek area, the first in Korea to apply the PSM (Precast Span Method); Pungse Bridge, the longest railway bridge in Korea with a total length of 6,844 m, constructed across the Pungse Plain from Cheonan City Pungse-myeon to Yeongi-gun Sojeong-myeon; the Hwanghak tunnel which is the longest tunnel in Korea in the 1st phase with a total length of 9,975m, passing through Hwangaksan Mountain, 1,111 m above sea level, from Chungbuk Yeongdong-gun to Gimcheon City, Gyeongsangbuk-do.

(2) Track

The high-speed railway track in the 1st phase section basically laid UIC rail with proven performance and adopted a 35-cm thick gravel track. Track work must maintain strict construction precision, ensuring that the elevation difference of the completed track satisfies a precision of less than 2 mm while carrying out a long stretch of construction within a short construction period. So, it was necessary to completely mechanize construction, breaking away from the domestic track work practice of relying on human construction. There was a need to function efficiently as an advanced base for track laying, such as bringing in equipment and pre-storing materials, and as a base for maintenance after completion. Therefore, they were placed at intervals of approximately 40km where the main line of the high-speed railway connects to the existing railway. In the 1st phase section, main bases of approximately 20,000 pyeong with facilities for hosting, maintaining, and refueling track equipment and storing track materials will be installed in Osong, Yeongdong, and Yakmok. An auxiliary base measuring approximately 4,000 pyeong, capable of housing some equipment and conducting simple inspections, was constructed in Hwaseong Cheonan Gomo.

Gyeongbu high-speed railway track was manufactured by flash, but electric welding of twelve

25-m straight rails at the Osong track base into a 300-m long rail. Unlike the tracks of the general railway in the past, where 20~25m standard rails were connected with joint plates and bolts, it was transported to the construction site by special freight cars and laid with continuous welded rails connected by termit welding. The railroad switch for high-speed railways is very long because of the increased radius of the curve on the side of the turnoff and the adoption of a movable crossing with no connection parts. In areas where it is difficult to lay continuous welded rails due to unique bridges or branching machines, expansion joints are installed at the ends of the rails to eliminate connection parts.

(3) Train Station Architecture

Among the high-speed railway train stations of the 1st phase project, Gwangmyeong Station and Cheonan-Asan Station, located in the High-speed New Railway line section, were built under the responsibility of High-Speed Rail Construction Corporation. High-Speed Railway Gwangmyeong Station is the representative train station of the Gyeongbu high-speed railway, which expresses the image of a cutting-edge high-speed railway by using high-tech glass, steel frame, and stainless steel roof on the exterior of the building. Cheonan-Asan Station built a future-oriented image by building the train station roof structure installed on the high-speed railway bridge to symbolize the flight of a crane flying from the ground toward the sky. Seoul Station and Yongsan Station, located on the existing line section, were built as on-board train stations by the Korean National Railroad, attracting private capital. Unlike Yeongdeungpo Private-Invested Railroad Station, the railway station and private commercial space are separated in two dimensions, and sufficient train station space is secured. It was built as a commercially successful large-scale train station while minimizing the shortcomings of the past Private-Invested Railroad Station method. Daejeon·Dongdaegu·Busan Stations located in the existing line utilization section are Korean National Railroad entrusted projects. The 1st phase train station was designed considering scalability in the 2nd phase project. While realizing the image of a state-of-the-art train station, user-centered convenience, economic efficiency, and ease of management were also considered.

(4) Railway Electrification & Electricity

Gyeongbu high-speed railway received 3-phase 154kV power from the KEPCO electrical substation, transformed it into single-phase 55kV from the main transformer (Scott connection) and single-phase 25kV from the autotransformer, and constructed electrical substations at seven locations (Seoul Vehicle Depos, Ansan, Pyeongtaek, ShinCheongju, Okcheon, Gimcheon, Busan Vehicle Depos) at intervals of about 50km to supply the power to the catenary. In order to compensate for voltage drops and reduce telecommunication-induced disturbances, power distribution stations were installed at 7 locations between electrical substations, and parallel feed stations were installed at 13 locations at intervals of approximately 10km.

High-speed railway catenary was included in the contract to introduce TGV core technology. France CEGELEC supplied the basic design and necessary equipment and transferred the technology to domestic companies through detailed design, construction supervision, and training. In order to secure dynamic compatibility with vehicle pantographs running at high speeds, elaborate construction with a construction tolerance of mm was required; therefore, after the track location was confirmed on site, a new method was introduced to calculate and print all facilities, including electric poles, brackets, and droppers, and install them with equipment using LEXCAT, a French catenary design program.

In particular, to prevent damage to already completed facilities while carrying out electrical work after completing the roadbed or track, the best quality was secured by introducing a construction method that reflects ‘civil engineering-related electrical equipment’ such as C channels and subway pole foundations at the civil engineering design stage. We also built a power system, a ‘supervisory control and data acquisition’ (SCADA) system, that can remotely monitor, control, and operate 200 pieces of power equipment between Seoul and Busan in real-time from the central control room.

(5) Signal Control & Safety Equipment

Gyeongbu high-speed railway signal control equipment is included in the core technology introduction contract, and in order to safely operate trains at 3-minute intervals at a maximum speed of 300 km/h, using French TGV's TVM430 (onboard signaling system), Automatic train control system (ATC), electronic interlocking system (SSI) with excellent safety and reliability, and train concentration control system (CTC) were installed.

In particular, various safety monitoring devices that did not exist in general railways were introduced to ensure the safe operation of high-speed railways. ‘Hot Box Detector’ is a device that measures the axle temperature of a running high-speed vehicle and provides information to CTC and ATC in case of overheating to slow down or stop the vehicle. It was installed at intervals of approximately 30km. The ‘intrusion detector’ is a device that installs detection lines in areas where falling rocks or car intrusions are likely to occur on the track. When an obstacle intrudes on the track, it transmits information to the ATC device and slows down or stops adjacent trains. The ‘dragging equipment detector’ is a device to prevent damage to facilities on the track that occurs when vehicle parts or attachments fall off and are dragged under the vehicle. It was installed at the point where the existing line or repair base enters the high-speed railway line. A ‘Meteorological detector’ is a device that detects weather conditions such as rainfall, snowfall, and strong winds along the track and transmits them to CTC. They were installed at intervals of approximately 20km along the track so that operators could prevent accidents by slowing down or stopping trains in the event of heavy rain, snow, or typhoons above a certain level. In particular, a seismic acceleration measurement system was installed at major train stations, and tracks were created to control trains immediately and prevent damage in the event of an earthquake. A dedicated line was established between the Korea Meteorological Administration and the high-speed railway control room. The high-speed railway structure was designed to withstand a magnitude 6.0 earthquake sufficiently.

(6) Telecommunication

Along the Gyeongbu high-speed railway tracks, common pipeline facilities (cable troughs) were installed to accommodate and protect power, telecommunication, and signal cables, improving the safety and convenience of maintenance. An optical cable was laid here, and transmission facilities were configured with a circular network in synchronous optical transfer mode in order to enable optical transmission of various information such as train operation information, train wireless information, and power remote control information required for high-speed railway operation. This circular network was made redundant so that it could be switched to a spare transmission network as soon as a failure occurred in any section. The high-speed railway control room also installed a transmission network management system that can remotely monitor and adjust all transmission facilities installed in the 1st phase section.

The existing railway train wireless system was a 150-MHz band VHF space wave type, so there were limitations in call quality. In the Gyeongbu high-speed railway's 1st phase project, a contract was signed with USA Motorola. In order to connect many users through a small channel through a repeater, we introduced the TRS (Trunked Radio System)-ASTRO system, a frequency-sharing method in the 800MHz band that applies technology that automatically allocates channels. This wireless facility not only supports high-quality wireless telecommunication for maintenance of facilities such as tracks, tram lines, signals, and telecommunication, as well as operation information exchange and train control between trains running at a high speed of 300 km/h and ground stations. Besides, efficient operation is possible by wirelessly transmitting data for information exchange in real-time between the speed train on-board computer and the ground computer at CTC or Vehicle Depots.

Section 4 Improvement of Existing Line Electrification and Honam Line Electrification Project for High-speed Train Operation

1. Organization in charge of Korean National Railroad's High-speed Railway Project

After the Gyeongbu High-Speed Railway's 2nd modified plan, the total amount of consignment project costs to be handled by the Korean National Railroad has increased significantly, reaching KRW 1.7503 trillion. In order to meet the high-speed railway opening schedule, it was necessary to adhere to a tight process plan that required all projects to be completed by the end of 2003. Korean National Railroad integrated high-speed railway-related organizations and personnel in August 1999. It launched the high-speed railway Headquarters, consisting of 6 divisions and 20 teams, including the high-speed railway Project Division, Operations Division, Facilities Division, Electrical Division, Vehicle Division, and Technology Development Division. The High-speed Rail Construction Project Commercial Office was launched, consisting of 7 departments and 25 divisions, including the Detailed Design Division, Quality Control Division, Track Division, Civil Engineering Division, Architectural Machinery Division, Subway Power Division, and Telecommunication Signal Division. High-speed railway-related construction work was integrated and implemented.

The high-speed railway's electrification improvement and facility maintenance project for the existing line utilization section needed help carrying out various improvement works on the Gyeongbu Line, which has the highest number of train operations in Korea. In response, we developed a Windows-based railway construction project management system (Open Plan), and we have established a project management system in the high-speed railway business department that coordinates the work schedule plan in detail with the technology PM for each process by appointing a regional PM. A 'Train Coordination Team' was newly established and operated to establish a train coordination plan for each construction schedule and consult with the railway control room with corporation to control train operation.

Some masonry tunnels on existing lines built during the Japanese colonial period were low in height, so improvement was essential for electrification for high-speed train operation. High-speed Railway headquarters laid temporary crossing lines between the upper and lower tracks at both ends of a certain section, including the tunnel to be improved, installed a two-way signal system, and developed the first method to reduce train delay to less than 5 minutes, and were able to ensure safe train operation and sufficient work time. The effective project management system, train coordination team operation, and tunnel improvement construction method developed at the time were later widely applied to railway construction projects.

Meanwhile, Korean National Railroad negotiated with the French National Railways International Project sector (SNCF-I) from October 2000, when the existing line improvement project began in earnest, until the opening of the high-speed railway, and brought in experts from France National

Railways who are veterans in each field, and also requested the Korea Railroad Research Institute to dispatch professional researchers to serve as partners in each field, and a 'High-speed Railway Technology Advisory Group' was formed. The high-speed railway technology advisory group resided with the high-speed railway headquarters staff. It provided opportunities for discussion by experts in a wide range of fields, ranging from design review and advice on facility improvements for high-speed train operation on existing lines to the establishment of operation and maintenance regulations for high-speed railways and through this, Korean National Railroad was able to minimize trial and error. French railway experts are reviewing the safety of high-speed vehicles on existing lines in various fields such as track, bridge/tunnel, tram line, signal, power EMI, and train operation/safety equipment, and contributed to the success of Korea High-speed Railway by generously sharing the know-how accumulated through many years of TGV operation.

2. Honam Line Electrification Project

The project to electrify existing lines so that high-speed trains can operate was not simply electrification for the operation of electric vehicles but was a modernization project covering all areas such as improvement of signal telecommunication equipment, reinforcement of vulnerable points in the roadbed, support of track such as lengthening of rails and elasticity of turnouts, modification of station premises and facility maintenance including installation of platform roof, etc. In particular, when improving electrification, we promoted a project to make most of the railway crossings, where collisions with cars were frequent, three-dimensional. In the case of the Daegu-Busan section, a sharp curve part linearization improvement project with a curve radius of less than 600m was implemented. In this way, the Gyeongbu Line Electrification Project related to high-speed railway served as an opportunity to transform the main railway network into a modernized electric railway network on a different level from the past industrial railway electrification for coal transportation or the Metropolitan Railway construction project for electric train operation.

The Honam Line Electrification Project significantly contributed to organically integrating high-speed railway routes into the existing railway network, expanding the areas benefiting from high-speed train services, and accelerating the time to improve railway efficiency. Railway electrification between Daegu and Busan on the Gyeongbu Line began as a temporary alternative route included in the 1st phase project of the Gyeongbu high-speed railway. The Honam Line Electrification Project is a mainline electrification project directly promoted by the Korean National Railroad, separate from the high-speed railway construction project. Afterward, it catalyzed the promotion of electrification of major main lines such as the Jeolla Line and Gyeongjeon Line.

Even though the Kim Dae-Jung Government from Honam was launched in mid-1999, the opening of the Honam high-speed railway construction project had to be delayed until after 2011 to overcome the IMF economic crisis. Jeong Jong-hwan, President of the Korean National Railroad, placed the Honam Line Electrification Project on the list of projects subject to the Ministry of

Planning and Budget's Preliminary Feasibility Study. High-ranking government officials initiated A feasibility study for the Honam Line Electrification Project in 2000. In April 2004, a plan was proposed to open simultaneously with the Gyeongbu High-speed Railway’s 1st Phase. When President Gwangju visited in November 1999, The Blue House Senior Secretary for Economic Affairs gave a boost by announcing the Honam Line Electrification Project promotion.

In December 1999, the Korean National Railroad high-speed railway headquarters established the ‘Honam Line Electrification Project Promotion Plan’ with a total project cost of KRW 875.5 billion for electrification, station interior improvement, and track and structure reinforcement. The plan was to share the Gyeongbu high-speed railway route between Yongsan Station and Seodaejeon Station and introduce high-speed trains by electrifying the Honam Line between Seodaejeon Station and Mokpo Station. According to this plan, the train operating time between Seoul and Mokpo in April 2004 will be reduced to 2 hours and 58 minutes (Seoul-Gwangju 2 hours and 38 minutes), which is 1 hour and 36 minutes shorter than Saemaul-ho's 4 hours and 34 minutes at the time. It was a plan. For the high-speed vehicle, according to the stage-specific construction plan of the Gyeongbu high-speed railway, the utilization plan of 46 trains, which had some room compared to the predicted demand at the beginning of opening, was adjusted. Here, the goal was to run 32 trains on 83 trains one way on the Gyeongbu axis, 10 trains on 20 trains on the Honam axis, and 4 trains on maintenance. It was analyzed that it would be able to meet the predicted demand of Gyeongbu and Honam in 2006. After 2006, additional purchases were planned for the required vehicles, which later led to the ordering of the domestically developed KTX-Sancheon.

As a result of the Preliminary Feasibility Study in the first half of 2000, B/C was found to be 1.29~1.32, showing high economic feasibility. Beginning in the second half of the same year, the Korean National Railroad immediately commissioned the Korea Railroad Research Institute and began work on establishing a basic plan. As a result of the service, the total project cost was adjusted to KRW 994.4 billion. After establishing a basic plan, the Honam Line involves only simple electrification without linear improvement. The basic design of Gyeongbu Line Electrification was applied, and detailed design started immediately. The construction period was shortened through careful project management, such as beginning construction for each construction section and ordering required subway facility materials simultaneously.

As a result of the Preliminary Feasibility Study in the first half of 2000, B/C was found to be 1.29~1.32, showing high economic feasibility. Beginning in the second half of the same year, the Korean National Railroad immediately commissioned the Korea Railroad Research Institute and began work on establishing a basic plan. As a result of the service, the total project cost was adjusted to KRW 994.4 billion. After establishing a basic plan, the Honam Line involves only simple electrification without linear improvement. The basic design of Gyeongbu Line Electrification was applied, and detailed design started immediately. The construction period was shortened through careful project management, such as beginning construction for each construction section and ordering required subway facility materials simultaneously.

Section 5 High-speed Railway Operation Preparation and Commissioning

1. Establishment of a Comprehensive Plan for High-speed Railway Operation Preparation and Training of Operating Personnel

The Korean National Railroad established the "Comprehensive Plan for High-speed Railway Operation Preparation" in July 1995. It established the "High-speed Railway Operating Personnel Training Plan" as a specific action plan in August of the same year. What is noteworthy is that considering the reality that the Korean National Railroad at the time had very few working-level personnel fluent in foreign languages, 80 elite personnel in each field were selected as instructors and provided intensive prior language training for about a year to lower the barrier to technology transfer that occurs when only interpreters who do not know much about technology are used. Thanks to this language training and subsequent overseas training, language barriers were overcome in each technology field, and technical documents in English and French were widely translated and digested, which served as an opportunity to improve railway operating technology.

In March 1996, France's training for vehicle field technology managers was initiated. From September 1996, vehicle field instructors were dispatched to France for 34 to 69 weeks of training, depending on their field of expertise. Also, in September of the same year, after negotiations with the Korean National Railroad, a training contract was signed at the French railway site for six non-core fields, including France National Railway's international project sector (SNCF-I) and track repair, and stepwise training began.

In terms of operating personnel training, advanced training techniques were introduced, unlike the traditional training methods of existing railways. The 'High-speed Railway Training Division' was organized at the Training Institute for Railroad Civil Servants (Railroad Human Resources Development Institute) for domestic training of high-speed railway operating personnel. While installing the 3D high-speed railway driving simulator (FTS) included in the high-speed vehicle introduction contract, we have built cutting-edge practice facilities such as Computer-Aided Instruction (CAI) for training in each technology field, including high-speed vehicles. Instructors who completed training dispatched to France were brought in to develop training content.

2. Establishment of an Integrated Railway Information System and Finalization of the KTX Logo

In the second half of 1998, regarding the project to build an information system such as the high-speed railway reservation and sales system, which conflicted with the Korean National Railroad as the High-Speed Rail Construction Corporation has been trying to build an independent system, following the confirmation of the 2nd modified plan, it was agreed to build an integrated system with the general railway. In the end, this project was promoted by the Korean National Railroad, and we began building the ‘Integrated Railway Information System (IRIS)’ for reservation sales, customer management, train operation plan, revenue management, and station automation. The station automation equipment involved installing automatic ticket machines, automatic dog kennel signs, travel information guides, etc., at 17 stations where high-speed trains stop and introduced wireless terminals for crew members. The project cost to build the Integrated Railway Information System is substantial for an IT project, reaching KRW 104.8 billion. From December 2000 to December 2004, a task force organization called ‘High-speed Railway Integrated Information Promotion Team’ was formed and operated. The 1st phase project, including pre-order sales, was completed in November 2003, and the 2nd phase project, including revenue management, was completed in December 2004.

As a result of a service hosted by High-Speed Rail Construction Corporation in July 1999, the name of the High-speed Railway system was established for marking high-speed vehicles. We decided on ‘Korea High-speed railway’ in Korean and KTX (Korea Train eXpress) in English and finalized the logo.

3. High-speed Railway Test Line Construction and High-speed Rolling Stock Test Operation

The test line section was a high-speed railway route between Cheonan and Daejeon with a total length of 57.2km, of which 34.4km was completed in October 1999. As for the high-speed vehicle, Korea-type TGV No. 2 was brought into Korea in April 1998, and after the completion of the test line, it was put into service and began test operations at 200 km/h. By September 2000, the total length of each section of the test line was expanded to 54.1km. Afterwards, for about 52 months, the speed of Korea-type TGV No. 2 was increased by stage from 40 km/h to 300 km/h. A total of 180 tests were conducted to confirm the performance and safety of the high-speed railway, including vehicle adjustment, performance, acceptance, and comprehensive tests. Meanwhile, Korea-type TGV No. 1 continued its test operation on the SNCF (Société Nationale des Chemins de fer Français) route and compared it with domestic test operation results.

In January 2001, before the high-speed vehicles full-scale acquisition and test operation, the High-speed Rail Construction Corporation signed an ‘Agreement on Korean National Railroad Employee Dispatch and Service.’ High-speed railway engineers and vehicle maintenance personnel who completed training and were dispatched to France were dispatched to the Corporation to support test operations. In December 2001, when the size of the dispatched workforce increased, in the presence of the Ministry of Construction and Transportation, an ‘Agreement on establishing an integrated operation support organization and operation and maintenance of operating facilities’ was signed between Korean National Railroad and the Corporation. An integrated organization was created with Corporation employees, and Korean National Railroad dispatched employees to conduct test operations and maintenance work on high-speed railway vehicles and facilities.

4. Preparation Situation Management of High-speed Railway Operation

In December 2001, the Ministry of Construction and Transportation recognized the importance of high-speed railway operation preparation work. It established a “Comprehensive Plan for High-Speed Railway Operation Preparation (Ministry of Construction and Transportation),” in which the operating entity, Korean National Railroad, and the construction entity, High-Speed Rail Construction Corporation, participate. In January 2002, the Ministry of Construction and Transportation established a ‘High-speed Railway Operation Preparation Team’ to host periodic inspection meetings. In accordance with the Ministry of Construction and Transportation's comprehensive plan for high-speed railway operation preparation, Korean National Railroad established an advanced management system by dividing into seven areas including operating organization and human resources training, operating system, sales strategy, test drive, high-speed rolling stock maintenance, handover, and opening preparation; 26 unit projects and 1,100 detailed tasks.

In April 2003, it was decided to unify the high-speed railway opening period and open Seoul~Busan·Mokpo simultaneously. In fact, in the first modified plan, the Seoul-Daejeon section was scheduled to open in 2000, and the Seoul-Busan section was expected to open in 2002. Still, in the 2nd revised plan, the route between Seoul and Daejeon was changed to open in December 2003, and the route between Seoul and Busan was changed to open in April 2004. Nevertheless, the Korean National Railroad's proposal to open it all at once was accepted to avoid inefficiencies caused by separate openings at the train commissioning stage and public confusion due to train schedule changes within four months.

In the first half of 2003, it was decided to require operating personnel for the high-speed railway, which would greatly increase productivity compared to the general railway, which had approximately 30,000 operating personnel. Of the total required 2,676 people, 977 were to be filled through outsourcing, KNR employees were limited to 1,699, new additions were limited to 249, and 1,111 people were transferred from general railways. The remaining 339 people were already assigned to high-speed railway-related organizations.

From the second half of 2002 to the first half of 2003, when the promotion of railway structural reform faced difficulties due to the High-Speed Rail Construction Corporation's union refusing to cooperate while insisting on the legitimacy of separate operation of high-speed railway, preparations for operating the high-speed railway have suffered severe difficulties. However, this conflict situation finally came to an end when the new government, launched in March 2003, changed direction to publicize the Korean National Railroad rather than privatize it, and in July 2003 when the Framework Act on Railroad Industry Development and the Korea Rail Network Corporation Act, which are the essential railway structural reform bills, were enacted.

In August 2003, Korean National Railroad made preparations for high-speed railway operation a priority task at the high-speed railway headquarters but also across all organizations of the Korean

National Railroad. To solve problems arising during operational preparation, such as high-speed railway commissioning, as a task force organization with a vital control function, the ‘High-speed Railway General Control Room’ was launched with the Korean National Railroad deputy director as the director and the ‘General Coordination Bureau’ with the secretariat function was newly established. The General Coordination Bureau performed process management for various projects. It made decisions quickly through weekly inspection meetings hosted by the Deputy Director. It was responsible for external cooperation with the Ministry of Construction and Transportation and High-Speed Rail Construction Corporation, high-speed train test drive management, and opening event preparation work.

5. Unification of Opening Preparations with the Korean National Railroad and Opening Ceremony

In late August 2003, a ‘Business Agreement for Opening and Operation of High-speed Railway’ was signed between Korean National Railroad and High-speed Rail Construction Corporation in the presence of the Ministry of Construction and Transportation, and agreed to unify opening preparations for the Korean National Railroad from September 1, 2003. By this agreement, it was decided to carry out acceptance testing and integrated testing of high-speed railway vehicles, as well as facility and electrical fields, under the responsibility of the Korean National Railroad through in-kind handover before legal handover. Corporation personnel performing related tasks, such as high-speed vehicle contract management, were dispatched to the Korean National Railroad.

Immediately after the agreement to unify opening preparation work, Korean National Railroad recognized the serious problem of delaying the vehicle acceptance test schedule in a meeting with EUKORAIL, a high-speed vehicle supplier, to identify pending issues. It took emergency measures to accelerate the acceptance process. The acquisition will be carried out under the operator's responsibility, mobilizing as many available human resources as possible and continuing to supplement some items difficult to test due to seasonal factors through maintenance even after opening. Beginning with the completion of the final acceptance inspection of the first series at the end of August 2003, acceptance tests for 46 units were conducted one by one, and the acceptance of all units was barely completed in late March 2004, just before opening.

Korean National Railroad launched the ‘High-speed Railway Integrated Commissioning Team’ under the high-speed railway headquarters in September 2003. Integrated commissioning was implemented to check and inspect various driving regulations and procedures, including high-speed railway vehicles and existing line interface testing, verification of compatibility between high-speed railway lines and existing line connection sections, strategies for handling exceptional cases when operating high-speed trains, etc.

In November 2003, the high-speed railway regular operating organization was launched. The high-speed railway headquarters was changed to the high-speed railway project headquarters, and a

High-speed Railway planning division, sales division, and transportation division were established. high-speed railway facility division, electricity division, and vehicle division were transferred to the facilities, electricity, and vehicle headquarters, respectively. A high-speed railway field operation organization, including a high-speed railway CTC command center, high-speed railway locomotive/train crew office, high-speed railway facilities, electrical office, high-speed railway vehicle maintenance base, etc., was also launched, deploying 2,676 stepwise professional personnel, and began on-site proficiency training.

From January 2004, commercial commissioning, including real-time verification of train plan tables for all sections, passenger handling tests according to virtual scenarios, customer information system testing, and inspection of convenience facilities was conducted along with on-site adaptation training for operating personnel. A general train relocation plan after April 2004 was also carefully established to simultaneously check the preparedness of the customer information and reservation system to ensure clarity due to temporary changes. In particular, for four days from March 19th to 22nd, all trains were operated according to the integrated train operation plan at the opening time. The operation system was finally checked, and deficiencies were corrected through a whole load test similar to the actual situation.

Unlike the existing method, where the opening event was held on the day of business opening, which resulted in customer inconvenience and many restrictions on event progress, the high-speed railway opening event was scheduled separately ahead of the business start date, allowing the opening train test drive event to proceed smoothly in a national festival atmosphere. On March 24, 2004, the Honam Line Double Track Electrification Project completion ceremony was held at Mokpo Station Square. On March 30, the Gyeongbu high-speed railway's 1st phase opening ceremony was held at Seoul Station Square. At the time, President Roh Moo-Hyun was in the midst of an impeachment phase, so Prime Minister (Acting President) Goh Kun attended. The high-speed train at the opening ceremony took VIPs and ran at 300 km/h along the high-speed railway line from Seoul Station to Daejeon Station via Gwangmyeong Station. Many media outlets, including live TV broadcasts, conveyed the excitement of the opening of the High-speed Railway.

02

KTX: 20 Years of History

High-speed Rail Network Expansion

02 High-speed Rail Network Expansion

Section 1 Preface

Looking at Korea's train operation speed improvement process, before KTX began operating, the Saemaul-ho PP (Push-Pull) train on the Gyeongbu Line covered the distance between Seoul and Busan in 4 hours and 10 minutes at a maximum speed of 150 km/h; however, starting with the opening of Gyeongbu high-speed railway line's 1st phase (Seoul~Dongdaegu) on April 1, 2004, and following the beginning of the 2nd phase (Dongdaegu~Busan) and the construction of a high-speed railroad dedicated line in the Daejeon·Daegu urban section, currently, the Gyeongbu axis travel time has been shortened by almost half to 2 hours and 20 minutes.

Afterward, in order to expand the high-speed railway beneficiary area, in parallel with the high-speed railway new line construction project, we are continuously promoting the existing general railway improvement and high-speed conversion project. Currently, three high-speed railway routes, including the Gyeongbu·Honam·Suseo high-speed railway line, and three semi-high-speed railway routes, including Gyeongjeon Line, Jeolla Line, and Donghae Line, KTX and SRT, power car type high-speed trains with a maximum operating speed of 300 km/h, are in operation. The electric multiple unit type high-speed train KTX-Eum, with a maximum operating speed of 260 km/h, operates on three semi-high-speed railway routes, such as Gangneung Line, Jungang Line, and Jungbu Naeryuk Line.

What is noteworthy in the process of expanding Korea's high-speed railway infrastructure is that the design speed of 300 km/h was not unconditionally insisted upon during semi-high-speed railway construction and general railway improvement. As a result of analyzing project costs after the opening of the Gyeongbu high-speed railway line, there was a problem: high-speed railway construction costs increased significantly compared to general railways. A professional organization's research determined that the maximum design speed threshold that maximizes the time reduction effect without substantially increasing construction costs is 250 km/h. Accordingly, during newly constructed semi-high-speed railway and general railway improvement projects such as Gangneung Line, Jungang Line, and Jungbu Naeryuk Line, it is being constructed at a maximum design speed of 250 km/h.

With the opening of high-speed railways and Semi-high-speed Railways, high-speed trains that quickly connect metropolitan areas and regions are operated, providing high-speed train service to residents in small and medium-sized cities and large cities. This contributes greatly to the development of the local economy by securing the right to movement, which is one of the basic rights of citizens, promoting station influence area development around high-speed train stop stations, and transporting business demands and tourists. Besides, high-speed railway transportation demand has also increased from 40,000 passengers per day when Gyeongbu high-speed railway's 1st phase opened on April 1, 2004, to approximately 200,000 passengers per day, playing its role as a central means of transportation for the nation. In particular, the Gangneung Line remains an Olympic legacy following the successful hosting of the 2018 PyeongChang Winter Olympics by transporting the Olympic team (officials) without being affected by climate such as snowfall. Jeolla Line supported the successful hosting of the Yeosu EXPO by transporting 1.38 million of the 8.2 million visitors by rail during the three months of the Yeosu EXPO. It plays a crucial role in transporting 10 million Yeosu-visiting tourists annually.

Since the opening of the Gyeongbu high-speed railway, the three high-speed railways and six semi-high-speed railways currently in operation have established themselves as a key means of transportation between regions, and it is causing many impacts, such as reducing travel time between regions, developing the MICE industry, and promoting regional development. Accordingly, its influence is so significant that it determines the rise and fall of a region depending on whether a high-speed railway station is in the region. Therefore, the region is putting much effort into attracting a high-speed railway station.

Section 2 Opening of Gyeongbu High-speed Railway’s 2nd Phase Project and Gyeongjeon Line and Jeolla Line Electrification

1. Gyeongbu High-speed Railway’s 2nd Phase(Dongdaegu~Busan) Project

Gyeongbu high-speed railway’s 2nd phase project, which involves constructing a new high-speed line between Dongdaegu and Busan, began construction in 2002 ahead of schedule. The biggest challenge was environmental-related complaints at the Cheonseongsan Mountain in Yangsan, Gyeongsangnam-do, and Geumjeongsan Mountain passage sections in Busan. In December 2001, the Buddhist community and 26 environmental and civic groups from Busan, Ulsan, and Gyeongnam regions formed a countermeasures committee with monk Jiyul as executive chairman. They demanded the withdrawal of the construction plan and the change of route. In 2002, opposition was severe, with a pan-countermeasure committee consisting of the Buddhist community in Busan, including Beomeosa Temple, and about 50 civic groups, including the Busan Regional Federation for Environmental Movements and the Kyungsil Yeon, holding a rally and hunger strike in Busan. In the end, immediately after the inauguration of the participatory government in March 2003, the President's instructions halted all construction, and an investigation committee, in which even the opposing party participated, was formed to reexamine the route. In September 2003, the government decided there was no better alternative to the existing route and agreed to resume construction along the originally planned route. The opposing party even filed a lawsuit requesting construction suspension called the ‘Hynobius leechii lawsuit,' which was dismissed in the first and second trials. In the first half of 2004, ‘Jiyul’ occupied the construction site and appealed to the Supreme Court, and the uproar ended with the Supreme Court's dismissal decision in June 2006. The section in question was constructed using an eco-friendly method that reduces vibration and noise during tunnel excavation. Even in the subsequent monitoring stage, there were no environmental problems, such as the habitat of dragon farmers, proving that the high-speed railway is an eco-friendly means of transportation. After this uproar, it became difficult for some groups advocating environmental protection to receive sympathy from the public for their radical opposition to high-speed Rail Construction.

In August 2006, the basic plan for the Gyeongbu High-Speed railway’s 2nd phase project was changed to include the grounding of the Daejeon-Daegu downtown transit section and the construction of additional intermediate stop stations in three locations, including Osong, Gimcheon, Gumi, and Ulsan. Accordingly, the operating distance between Seoul and Busan increased from 412km to 418.7km, and the operating time was adjusted from 116 minutes to 130 minutes, but the demand base for High-speed railways was greatly expanded. The 2nd phase project cost increased from KRW 5.6981 trillion to KRW 7.19 trillion.

In July 2009, the construction of the Geumjeong Tunnel, the longest tunnel in Korea with a length of 20.3km, was completed, the 2nd phase of project 'roadbed construction' entered its final stage, and track laying construction began in earnest. In 1st phase of the project, gravel track ballast was adopted except for tunnels longer than 5km. In the 2nd phase of the project, considering that more than 60% of the route is a tunnel, the entire section was laid with concrete track using Germany's ‘Rheda 2000’ Method. The initial construction cost of a concrete track is approximately 1.4 times higher than a gravel track's. The maintenance cost was about 26%, making it highly economical, and it was analyzed to have excellent ride comfort and safety due to minimal track errors.

A noteworthy aspect of the Electricity 2nd phase project is that TRS-TETRA was introduced as a train wireless facility. TETRA, a digital TRS technology that is more advanced than the analog TRS introduced in the 1st phase of the project, has been adopted as a national disaster network in major countries in Europe and China. In Korea, TRS-TETRA was also installed in the high-speed railway’s 2nd phase section in accordance with the National Emergency Management Agency's integrated command wireless telecommunication network construction plan.

In the vehicle field, according to the basic plan for High-Speed Rail Construction, only light maintenance facilities will be installed in the 1st phase project, and heavy maintenance facilities will be constructed in the 2nd phase project before the KTX vehicle's heavy maintenance period arrives. In February 2008, heavy maintenance facility construction began at the high-speed railway Goyang Vehicle Depots and was completed in December 2009, providing all facilities necessary for high-speed vehicle maintenance.

In June 2009, when the 1st phase of the project opened, a ‘comprehensive plan for opening and operation preparation’ was established, and a dedicated task force organization was operated to promote and inspect each stage. From June 2010 to the end of September, a comprehensive test run, including facility verification testing and sales commissioning, was conducted, any shortcomings were resolved, and operating personnel were assigned to provide on-site adaptation training.

On November 1, 2010, the 128.6km Gyeongbu high-speed railway between Daegu and Busan began operating. The KTX travel time between Seoul and Busan was 2 hours and 18 minutes, 22 minutes shorter than the 1st phase's 2 hours and 40 minutes. The number of trains increased by 11 on weekends, and the service section was also partially adjusted. Looking at the KTX transportation performance in the four months immediately after opening, Busan Station, which has become more competitive, increased the most at 25.1%, and Seoul Station, the starting and terminal station on the Gyeongbu axis, increased by 21.6%. In particular, among the four newly built stations, the average daily usage of Ulsan Station, an additional stop station, was 9,383, more than double the 4,751 people of Singyeongju Station, which was planned as an intermediate stop station from the beginning. So, the feasibility of installing additional intermediate stations was proven. In addition, as a symbolic measure, the two new direct trains between Seoul and Busan showed the importance of a train operation pattern that shortens operating times due to its high competitiveness, with seats sold out early.

Purely domestic engineers carried out the 2nd phase project of the Gyeongbu high-speed railway. Therefore, along with the Korea-type high-speed train KTX-Sancheon, it was a meaningful project that raised our railway technology to a world-class level. The Honam high-speed railway and the Metropolitan Area high-speed railway, which were promoted after that, took a step forward to the optimization level by applying the experience and technology from the 2nd phase project of the Gyeongbu high-speed railway. Furthermore, Korea's high-speed railway technology was able to enter overseas markets.

2. Gyeongjeon Line Samrangjin~Jinju Double Track Train and High-speed Train Operation

At the same time as the opening of the high-speed railway's 2nd phase section, KTX was also operated on the Gyeongjeon Line. During the 1st phase of the project, the area benefiting from the high-speed railway was expanded to include Changwon and Jinju, large cities in the western Gyeongnam region, as well as Milyang Station on the Gyeongbu Line, which was concerned about the suspension of high-speed train service on the existing line.

The Gyeongjeon Line is the only main railway route connecting the southern region of the Korean Peninsula from east to west, but it is a route that has lost its competitiveness for a long time due to a lack of investment. Korean National Railroad implemented the 'Gyeongjeon Line improvement basic plan' in 2000 to strengthen the competitiveness of the Gyeongjeon Line. As a result of analyzing the 'Samrangjin~Jinju double-track train Project' as a separate project to operate a high-speed train on the Gyeongjeon Line during the service process, it was analyzed that sharing the route between Samrangjin and Jillye of the 'Busan New Port Behind Railway' Project, which is already being implemented, would be highly economical. Immediately, a detailed design for the 95.5km Double Track Electrification Project between Samrangjin and Jinju on the Gyeongjeon Line began, with a total project cost of KRW 1.7042 trillion, and construction started in December 2003.

The stop distance between stations is set at an average of around 15km to secure main railway competitiveness. The number of stations was significantly reduced compared to the existing Gyeongjeon Line by consolidating stations with low transportation demand. Actively reflecting the local government's future city plan, Haman Station and Jinju Station were relocated to the outskirts of the city.

The Samrangjin-Masan section first opened in December 2010, immediately after the opening of the Gyeongbu high-speed railway's 2nd phase, and the Masan-Jinju section opened in December 2012, nine years after construction began.

The Gyeongjeon Line KTX, which operated up to 24 times a day immediately after opening, shortened the travel time by 40-50% compared to the existing Mugunghwa-ho train—in terms of transportation performance, three months after opening to Masan, the newly built Changwon

Central Station had the highest number of passengers, with an average of 2,456 passengers per day. In the past, the number of people using Masan Station, the central railway station of Masan, Changwon, and Jinju, reached 2,395, an 82.8% increase compared to the previous year.

3. Jeolla Line Electrification and High-speed Train Operation

KTX service was launched on the Jeolla Line at a similar time as the Gyeongjeon Line, supporting the successful hosting of the Yeosu Expo. Jeolla Line is a main railway totaling 180.3km, branching from Honam Line Iksan Station and ending at Yeosu Station. Starting with the development of Gwangyang Port, which will form a 2-port system with Busan Port, the straightening improvement work of Sinri~DongSuncheon (119km), which had poor alignment, was launched in 1989. The stepwise modernization and semi-high-speed railway project was promoted by dividing it into four sections: Suncheon~Yeosu (40km), DongSuncheon~Suncheon (1.7km), and Iksan~Sinri (34.1km).

When the effectiveness of direct KTX operation was confirmed through Honam Line Electrification, which opened simultaneously with the Gyeongbu high-speed railway's 1st phase in 2004, the Jeolla Line Electrification Project to support Yeosu's bid to host the 2012 Expo was gaining momentum. In 2007, when hosting the Expo was confirmed, construction began on the Iksan~Sinri double-track train project, which was changed to a 'leased private project' (BTL). The Electrification Project has also been added to the ongoing improvement projects in other sections. In October 2011, double-track trains were opened for all sections of the Jeolla Line, and direct KTX service began. In April 2012, the Semi-high-speed railway Project, which raised the Jeolla Line KTX maximum speed to 230 km/h, was completed, shortening the KTX travel time from Yongsan Station to Yeosu Expo Station to 2 hours and 50 minutes.

Jeolla Line KTX functioned as the best transportation method connecting Seoul and Yeosu Expo; hence, of the approximately 8.2 million tourists who visited Yeosu during the 2012 Yeosu World Expo (May 12, 2012 - August 12, 2012), approximately 1.38 million used the railway. Even today, KTX plays a key role in transporting the 10 million tourists who visit Yeosu annually.

Section 3 Opening of Honam High-speed Railway's 1st Phase, Gyeongbu High-speed Railway's 2nd Phase (Daejeon·Daegu Downtown Passage Section), KTX Pohang Direct Connection Line, Suseo-Pyeongtaek High-speed Railway Line

1. Honam High-speed Railway's 1st Phase Project

The Honam High-speed railway was formalized in 1990 when the government announced the Gyeongbu High-speed railway construction basic plan, presenting a blueprint to promote construction together with the Dongseo High-speed railway to realize a half-day living area for the entire country. Immediately after the announcement, a feasibility study was commissioned by the Korea Research Institute for Human Settlements. From 1994 to 1997, the Korea Transport Institute conducted two rounds of services to establish the basic plan for the Honam High-speed railway construction. In the Honam High-speed railway feasibility study, the optimal solution is to share the Gyeongbu High-speed railway route between Seoul and Cheonan and build a stepwise High-speed New Line from Iksan to Gwangju with a route that branches off from Cheonan and connects directly to Nonsan. It was presented. In the project to establish the Honam high-speed railway basic plan, the alternative of branching from Cheonan and constructing stepwise was strongly proposed among the four route alternatives.

In this situation, although the detailed route change for the Gyeongbu high-speed railway was successful, the installation of Osong Station was postponed because the station's influence area had a population of over 1 million. Chungbuk actively advocated for the Osong branch. The decision to diverge from the Gyeongbu high-speed railway emerged as the most significant issue in promoting the Honam high-speed railway project. The Osong branch alternative presented in the original basic plan service was to only branch like the Gyeongbu high-speed railway Pyeongtaek branch, and the stopping station was to install Honam High-speed railway, Daejeon Station in Gongam-ri, Banpo-myeon, Gongju-si, with Daejeon's Yuseong·Noeun district and Gongju City as the station influence area. As if under a spell, Osong Junction replaced Daejeon Station construction in Banpo-myeon and transformed it into an Honam high-speed railway stop station, and stakeholders did not notice this change.

Due to the economic crisis resulting from the IMF bailout in 1997, the opening of the Honam high-speed railway was postponed to a later date. At the end of 1999, it was decided to first utilize the existing Honam Line for electrification to promote simultaneous opening with the Gyeongbu high-speed railway's 1st phase in 2004. In 2001, when the Gyeongbu high-speed railway's 1st phase of construction project accelerated with the completion of the test line and the Honam Line Electrification Project also began construction, at the same time reviewing the Honam high-speed railway's basic plan, traffic control began with the selection of a branch station with the Gyeongbu high-speed railway. From May 2001 to November 2003, the 'Honam High-speed railway Basic Plan

Investigation Study Service' was conducted under the supervision of the Korea Transport Institute. The Korean Society of Transportation was responsible for selecting routes and stopping stations separately to ensure fairness and objectivity. Gyeongbu high-speed railway Route alternatives branching from Cheonan, Osong, and Daejeon were reviewed, and the optimal alternative for each was presented. In particular, the Seoul~Gwangmyeong section, which utilizes the existing line of the Gyeongbu high-speed railway, is expected to reach its capacity limit by 2020. A 44.3km New Line construction plan was proposed between Seoul Gangnam (Suseo) and Hyangnam (Pyeongtaek). Although the investigation study service to establish the basic plan was completed in November 2003, According to the announcement of the New Administrative Capital construction plan, it was decided to select the branch station after the location of the administrative capital was decided.

In April 2004, high-speed train service began with the completion of the Gyeongbu high-speed railway's 1st phase and the Honam Line Electrification Project. Due to dissatisfaction with the low speed of the Honam Line high-speed train, which utilizes a long section of the existing line, demands for the rapid promotion of the Honam high-speed railway have increased. Meanwhile, the Yeongi and Gongju areas were confirmed as the location of the New Administrative Capital in May 2004; however, following the Constitutional Court's ruling that it was unconstitutional, it was finally decided to relocate only some administrative agencies. The 'Honam high-speed railway basic plan establishment supplementary service' was implemented from October 2004 to December 2005, and important policy decisions were made here to reflect these changing conditions. The scope of the Honam high-speed railway construction project has been narrowed from the Gyeongbu high-speed railway branch station to Mokpo, like the existing Honam Line, to increase economic efficiency. Since the Suseo-Pyeongtaek section is a problem due to the use of the existing line between the Gyeongbu high-speed railway Seoul and Gwangmyeong and is a route shared with the Gyeongbu high-speed railway, it will be excluded from the Honam high-speed railway project and promoted as a separate project. The Pyeongtaek ~ Junction Station section, which is shared with the Gyeongbu high-speed railway, was excluded for future review as it was judged to have capacity for a considerable period. As a result of an objective evaluation process with this changed project scope, the Osong branch route was selected, and the basic plan for Honam high-speed railway construction was confirmed and announced in August 2006. The main contents reflected in the basic plan are that the Osong-Gwangju Songjeong section will open in 2015 as the 1st phase with a total project cost of KRW 10.5417 trillion. The Gwangju Songjeong-Mokpo section is the 2nd phase and will be completed by 2017. It was decided to confirm it later, considering changes in conditions such as Muan Airport. The stop stations are Osong, Gongju, Iksan, Jeongeup, Gwangju Songjeong, and Mokpo, and a facility plan has been established, including constructing high-speed Vehicle Depots in Gwangju.

The Honam high-speed railway construction project proceeded without hesitation after announcing the basic plan in August 2006. By utilizing the know-how acquired in the High-speed

Rail Construction and operation process and by reexamining the high-speed railway design and construction standards established during the Gyeongbu high-speed railway's 1st phase project, we adjusted the track center spacing (5.0m → 4.8m), minimum radius of curve (7,000m → 5,000m), tunnel cross-sectional area (107.9㎡ → 96.7㎡), etc. Besides, optimization design standards were established, and design was implemented, including applying concrete tracks to all sections.

Honam high-speed railway roadbed construction began in May 2009 and was completed by the end of November 2013, with mainline construction covering 72.1km of the bridge, 45.2km of tunnel, and 65.0km of earthworks. With the technology accumulated, complex construction works such as Osong Overpass, Mangyeong-gang River Bridge, Galsan Bridge, Jeongji Overpass, and Gyeryong Tunnel were completed neatly.

In 2011, a plan for local production of major railway materials was established with the goal of using 100% domestically produced materials for the Honam High-speed railway. We succeeded in developing KCT-Ⅱ, a Korea-type concrete track structure that is more advanced than the foreign concrete track structure applied to the Gyeongbu high-speed railway's 2nd phase section. High-speed railway turnouts for concrete tracks were also domestically produced and applied to the Honam High-speed railway.

The Honam High-speed railway High-speed vehicle purchased 22 primary trains at a project cost of KRW 736 billion. Safety and reliability were significantly improved by improving the existing KTX-Sancheon, such as applying modular IGBT semiconductor devices to the power supply device.

In April 2015, the Osong-Gwangju Songjeong section opened as Honam high-speed railway's 1st Phase. KTX-Sancheon, which runs on the high-speed New Line at 300 km/h, covers the distance from Yongsan Station to Gwangju Songjeong Station in as little as 1 hour and 33 minutes. It was 1 hour and 6 minutes shorter than the 2 hours and 39 minutes when running the Honam Line Electrification route. The Yongsan-Mokpo route was covered in 2 hours and 5 minutes, 56 minutes shorter than the existing travel time, bringing the Honam region into the era of high-speed railway in the true sense.

2. Opening of All Sections of the Gyeongbu High-speed Railway

Among the Gyeongbu high-speed railway's 2nd phase project, the Daejeon·Daegu downtown passage section was finalized as ground construction in July 2005 and received implementation plan approval in November 2007. In December of the same year, a consignment agreement for the downtown section construction project was signed between the Corporation and the local government, and construction began sequentially in August 2008 and was completed at the end of July 2015.

On August 1, 2015, as the high-speed railway line was opened across all sections of the Gyeongbu high-speed railway, the driving distance between Seoul and Busan was shortened by 6.5km (423.9 → 417.4km), and the driving time was 2 hours and 10 minutes, which was about 8 minutes shorter than before. In addition, with the construction of a new high-speed railway exclusive line in the Daejeon-Daegu urban section (L=45.4km), the track capacity on which KTX can operate has increased 3.5 times from 70 to 240 one-way, and the train delay problem caused by the bottleneck phenomenon before opening has been fundamentally resolved.

The Daejeon downtown transit section is an 18.2 km section extending from the Gyeongbu high-speed railway Daejeon North Connection Line to the South Connection Line, with a total project cost of KRW 1,230.3 billion. In the 10.88km main line extension section, a dedicated high-speed railway line was built parallel to the outside of the Gyeongbu Line. The 7.32km long railway line maintenance project involves the three-dimensional improvement of 15 crossing facilities. Adjacent to the railway, a mixed-use space (46,640 ㎡) and a side road (10 m wide, 7.95km long) were opened and significantly renovated.

The Daegu downtown passage section extends 27.1 km from the Daegu North Connector Line to Dongdaegu Station, with a total project cost of KRW 1.3107 trillion. In the 15.52 km main line extension section, a dedicated high-speed railway line was constructed inside the Gyeongbu Line. The 11.58 km-long railway line maintenance project significantly improved a total of 16 crossing facilities by making them three-dimensional. It opened a mixed-use space (49,300 ㎡) and side roads (10 m wide, 8.10 km long) adjacent to the railway.

With this project, the Korea National Railway constructed the high-speed railway's Daejeon·Daegu downtown transit section above ground, reducing the high-speed railway construction project cost and improving operational convenience. The two local governments fundamentally solved the problems of habitual road traffic congestion and accidents by ultimately improving the crossing facilities that intersect with the railway in the city center. The city's competitiveness was further enhanced by shedding the old image of the area around the railway and reviving it by reorganizing road traffic in harmony with the city plan, constructing new side roads, and securing green space for facilities.

Points of note include reducing demolition costs by retaining the disused Daegu North Connecting Line and using it as a high-speed railway operation line by establishing Seodaegu Station on the Gyeongbu Line as a corporation consignment project for which Daegu City paid the total cost of the project in 2019. It was created as a KTX stop station. With the opening of Gyeongbu Line Seodaegu Station in March 2022, the inconvenience of residents in areas near Seodaegu Station, such as Dalseong-gun, having to travel for about an hour to use the high-speed railway Dongdaegu Station will be eliminated. This helped create a foundation for revitalizing the industrial complex in the western part of Daegu City.

3. KTX Pohang Direct Connection

High-speed railway service in the Pohang region was originally planned to connect with the Donghae Nambu Line (Ulsan~Pohang) and transfer at Singyeongju Station. In the final stages of construction of the Gyeongbu high-speed railway 2nd phase, it was decided to build a direct line connecting the Gyeongbu high-speed railway and the Donghae Nambu Line in front of Singyeongju Station to operate KTX directly to Pohang Station.

The Gyeongbu high-speed railway Pohang direct line construction project was conducted through a preliminary feasibility study and technology investigation process. It was carried out using a design and construction turn-key method for rapid implementation. Construction costs were covered by changing the total project cost by including it in the High-speed railway's 2nd phase project.

The KTX Pohang direct line began construction in June 2011 and opened simultaneously with the opening of Honam high-speed railway's 1st phase (Osong~Gwangju Songjeong) on April 2, 2015. By operating a high-speed train directly to Pohang, Korea's representative industrial city, travel time was reduced by about an hour compared to the alternative of connecting the Donghae Nambu Line transfer at Singyeongju Station. Accordingly, demand continued to increase after opening, and today, the number of passengers using the High-speed Railway Pohang Station reaches 15,000 per day, demonstrating the superior competitiveness of the direct operation method compared to the transfer-linked method.

4. Suseo-Pyeongtaek High-speed Railway Line Construction Project

As a follow-up measure based on the government policy to separately promote the Metropolitan Area High-speed Railway construction project along with the confirmation of the Honam high-speed railway construction basic plan in August 2006, the Suseo-Pyeongtaek High-speed railway line construction project began from October 2006 to December 2007, with the Korean Society of Transportation carrying out the 'Research on Ways to Improve the Metropolitan Area Railway Network' project. As a result of the service, a route connecting the Suseo~Dongtan~Pyeongtaek junction was presented as the optimal alternative for the Metropolitan Area High-speed Railway route. It was analyzed that the economic feasibility of simultaneous construction between Seoul~Gwangmyeong and Suseo~Pyeongtaek was the highest, and the spark for the construction of the New Line between Seoul and Gwangmyeong was also revived. The Ministry of Construction and Transportation, which set a policy objective of completing the Metropolitan Area High-speed Railway construction project simultaneously with the Honam High-speed railway, began establishing a basic construction plan in March 2008, immediately after researching plans to improve the Metropolitan Area Railway network.

Along with this service, a Preliminary Feasibility Study was conducted from July 2008 to August 2009; in this investigation, the route between Suseo and Pyeongtaek was proposed to be constructed with Suseo Station above ground but mostly underground so that it would come out above ground in the Pyeongtaek district and connect to the Gyeongbu high-speed railway. Among the deep metropolitan express railways that needed construction at the time, only the alternative of sharing the Samsung-Dongtan section with the Metropolitan Area High-speed Railway route was analyzed as securing economic feasibility (B/C: 1.05) and presented as the optimal alternative.

In the 'Metropolitan area High-speed Railway construction basic plan establishment' service implemented until October 2009, reflecting the results of the Preliminary Feasibility Study, a basic plan (draft) was created by reviewing technological content and establishing a route plan. Based on this, the basic construction plan was confirmed and announced in December 2009. The plan was to complete the high-speed railway on the 61.1 km route between Suseo~Dongtan~Pyeongtaek by 2014, with Suseo Station, Dongtan Station, and Suseo base as the main facilities, at a construction cost of KRW 3.7231 trillion.

The roadbed basics and detailed design began in April 2010, the project implementation plan was approved in May 2011, and roadbed construction began stepwise. In February 2012, it was decided to construct an additional Jije Station, and in December 2013, additional line construction for route sharing with the Samsung-Dongtan Metropolitan Express Railway was reflected. The project period was extended by one year from 2014 to 2015.

In June 2015, the Yulhyeon Tunnel, the longest tunnel in Korea with a length of 50.3 km, was completed three years and five months after construction began. The Yulhyeon Tunnel is the third longest tunnel in the world, passing through major new cities in the Metropolitan area, such as Bundang, Yongin, and Dongtan at 50m below the ground, and occupies 83% of the section between Suseo and Pyeongtaek. To ensure the safety of this tunnel construction, the opening of the Suseo-Pyeongtaek High-speed railway line was delayed by about one year and eight months from the Honam High-speed railway.

The Suseo-Pyeongtaek High-speed railway line began comprehensive test operations in August 2016; hence, after verifying facilities and inspecting the train operation system and sales facilities, the high-speed train SRT started commercial operation on December 9, 2016. A high-speed railway station was finally built in Gangnam, Seoul, where there had been no main railway, dramatically improving high-speed railway accessibility in the eastern part of Seoul and the southeastern part of Gyeonggi-do. The operation of the high-speed train SRT, which starts and ends at Suseo, has reduced travel time and expanded supply in the Metropolitan area and other regions. Compared to KTX, which starts and ends at Seoul Station and Yongsan Station, the travel time from Seoul to Busan was shortened by 8 minutes (4.5%), and the travel time to Mokpo was shortened by 12 minutes (8.6%). The number of high-speed trains running between Seoul and Busan increased 34 times (64%), and the number of running between Seoul and Gwangju increased 18 times (75%).

Section 4 Opening of Semi-high-speed Railways such as KTX Gangneung Line and KTX Jungang Line and Their Meaning

1. Wonju~Gangneung Semi-high-speed railway Construction & KTX Gangneung Line Opened

The semi-high-speed railway, first introduced on the KTX Gangneung Line, was a general railway construction project in which the entire project cost was constructed with financial support. Unlike high-speed railway construction projects, a significant portion of project costs are covered by bond issuance, and construction debt is repaid with track usage fee revenues. Like the Gyeongjeon Line KTX, KTX Gangneung Line demonstrated a new type of high-speed train service with a maximum speed of 250km/h without directly connecting to other high-speed railway routes. From the perspective of the Korea Rail Network Corporation and the Korea Railroad Corporation, this is a welcome method because it has sufficient competitiveness as a semi-high-speed railway without the burden of repaying construction debt. This is a very welcome service as the general public can use the high-speed train service, which has significantly shortened operating times, at a semi-high-speed grade fare cheaper than the high-speed railway.

High-speed railways running over 300 km/h are difficult to construct due to their low economic feasibility on routes with insufficient traffic demand to cover high project costs. Running trains at high speeds can secure competitiveness compared to other means of transportation; however, as the operation speed increases, the minimum radius of the curve becomes more extensive than that of a general railway, and the bridge/tunnel cross-section becomes wider. Besides, there is the need to construct a concrete box structure according to the dynamics of the bridge section. These all cause construction costs to rise rapidly. The Korea Rail Network Corporation, which has accumulated experience and technology through the construction of the Gyeongbu high-speed railway's 2nd phase, conducted 'research on optimizing cost-effectiveness compared to speed' in 2010 and derived an optimal design speed of 250 km/h to find the critical speed so that the construction cost is slightly higher than that of general railway, and the speed effect is maximized. Accordingly, a 250 km/h design speed was applied to general main railway new or improvement projects such as the Gangneung Line, Jungang Line, Jungbu Naeryuk Line, and Seohae Line, and were constructed as semi-high-speed railways.

The Wonju~Gangneung Line is a railway that travels the rugged Taebaek Mountains in Gangwon-do from east to west. Starting with a feasibility study at the Engineering Research Institute of Seoul National University in 1996, technology investigation and design were repeated several times, but construction did not begin. After more than ten years of twists and turns, in May 2010, the government support committee for the 2018 Winter Olympic Games decided to promote the Wonju-Gangneung railway construction, which is difficult to attract private investment, as a financial project. At the IOC General Assembly in Durban, South Africa, in July 2011, the bid to host the 2018 PyeongChang Winter Olympics was confirmed. The project gained momentum in this process as the Korean government guaranteed KTX operation between Incheon Airport and Gangneung before the Olympics.

When it was decided to proceed with the Wonju~Gangneung railway construction project, Korea Rail Network Corporation began detailed roadbed design in August 2010 and received approval for the detailed design plan in April 2012. As a result of reexamining the route by raising the optimal design speed to 250km/h in the detailed design, in the first basic design, the loop route was planned to be 150km long but was straightened to 120.7km. The Seowonju-NamGangneung section was constructed as a double track, but at the request of Gangneung City, the Gangneung downtown section was extended as a single track underground to reach Gangneung Station. The total project cost was KRW 3.7597 trillion, with six stations (Manjong, Hoengseong, Dunnae, Pyeongchang, Jinbu, Gangneung) and two signal stations (Daegwallyeong, NamGangneung).

The Wonju~Gangneung Semi-high-speed Railway has 34 tunnels, extending 76km, accounting for 63% of the total length of the route, and has 53 bridges, extending approximately 11km. In particular, the Daegwallyeong Tunnel is Korea's longest mountain tunnel, with an extension of 21.7km, and the world's 8th largest mountain tunnel. It was the most challenging construction work section as it had to be constructed at an average depth of 400m underground (maximum depth of 780m) to minimize environmental damage to the Taebaek Mountains.

In the electric field, the 250 km/h KR Catenary system (KR ECS), developed with pure Korean technology, was applied for the first time. In addition, an ATP train control system using an onboard computer was installed, and domestic LTE-R train wireless, which optimizes LTE, the 4th generation wireless telecommunication technology, for the railway environment, was installed for the first time. LTE-R has been improved to provide high-quality audio service and high-capacity data and video service of up to 100Mbps so that the safety and convenience of train operation have been greatly enhanced by allowing trains, control centers, maintainers, operating agencies, and government agencies to exchange information through super-high-speed wireless telecommunication.

The 2018 PyeongChang Winter Olympics Support Project, handled by the Korea Rail Network Corporation, aimed to operate a high-speed train to connect Incheon International Airport to Gangneung quickly. Therefore, in addition to Wonju~Gangneung Semi-high-speed Railway (120.7km) construction, Incheon International Airport No.2 passenger terminal connecting railway (6.4km) construction & existing line (Susaek~Seowonju: 108.4km) semi-high-speed Project are also included. It has been done. The existing semi-high-speed project was divided into the following two projects and completed promptly: The 1st phase construction to build a new platform at Jungang Line Cheongnyangni Station to enable high-speed trains and to improve the existing track to allow high-speed trains to pass through Mangu Station; the 2nd phase construction to improve 'ShinGyeongeui Line (Susaek~Yongsan), Gyeongwon Line (Yongsan~Cheongnyangni), and Jungang Line (Cheongnyangni~Seowonju) signal system (ATS) for general trains and general track turnoffs' to the signal system (ATP) for high-speed trains and nose operation switch for high-speed railway tracks. Accordingly, the high-speed train's maximum speed was raised from 100 km/h to 150 km/h in the Gyeongwon Line Yongsan~Cheongnyangni section (12.7km), a metropolitan area subway operation section. In contrast, in the Jungang Line Cheongnyangni~Seowonju subway section (86.4km), the maximum speed was increased from 150 km/h to 230 km/h. In this way, high-speed operation of KTX became possible.

In December 2017, ahead of the PyeongChang Winter Olympics, the 120.7km double-track train between Wonju and Gangneung was opened as a semi-high-speed railway with a maximum speed of 250km/h, allowing KTX to run from Seoul Station to Gangneung Station in the shortest time of 1 hour and 54 minutes. The PyeongChang Winter Olympics were held in a mountainous area. Hence, transportation infrastructure conditions could have been better, and the snow rink, ice rink, athletes' village, and media village were separated. With the opening of the Wonju~Gangneung Semi-high-speed Railway, Olympic teams, and tourists could travel quickly from Incheon International Airport to the vicinity of Gyeonggi Stadium without transferring. During the Games, KTX operated 4,135 times, transporting over 1.06 million visitors, including top-class foreign guests from each country, and was considered a significant contributor to the success of the Olympics.

It takes about 6 hours to travel from Cheongnyangni to Gangneung by using the existing Mugunghwa-ho train, and about 3 hours to travel from Seoul to Gangneung by using the Express bus. Even after the Winter Olympic Games are over, after the opening of the Gangneung Line KTX, a new chapter in Gangwon-do tourism was opened with a speed revolution that covered the same section in 80 minutes.

2. Jungang Line(Wonju~Jecheon~Andong), Jungbu Naeryuk Line(Bubal~Chungju) Semi-high-speed Railway

The Jungang Line is the central railway connecting Cheongnyangni to Gyeongju, and along with the Taebaek Line and Chungbuk Line, it has supported economic development as an industrial railway that mainly transports coal and cement; however, in the 2000s, as domestic energy consumption shifted to oil and city gas, the share of freight transport fell sharply. Hence, a double-track train improvement project was carried out belatedly for use as a Metropolitan Railway route in the Metropolitan area. In order to effectively promote the project due to the long route extension, it was promoted by section and stage as follows: the 1st phase Cheongnyangni~Deokso, the 2nd phase Jecheon~Dodam; the 3rd phase Deokso~Wonju; the 4th phase Wonju~Jecheon, the 5th phase Yeongcheon~Sin-Gyeongju, the 6th phase Dodam~Yeongcheon. Except for the Dodam~Yeongcheon section, improvement projects have been completed to the extent of the current double-track train facility. The 6th phase, Dodam~Yeongcheon, is the last improved section. First, the route between Dodam and Andong opened in January 2021 as a double-track roadbed + electrified single track. Accordingly, the travel time from Cheongnyangni to Andong by Mugunghwa-ho train, which was

3 hours and 54 minutes, was shortened to 2 hours by introducing the electric multiple unit type, semi-high-speed vehicles KTX-Eum. The number of trains has also doubled from 14 to 24 per day, significantly improving accessibility to Jungbunaeryuk and the Metropolitan area. The Andong-Yeongcheon section is under construction with the goal of completion by the end of 2025 and opening a double-track train for the entire Jungang Line.

The Jungbu Naeryuk Line shares the Gyeonggi Gwangju Station~Bubal Station section of the Metropolitan area subway Gyeonggang Line (Pangyo~Yeoju) starting from Suseo, and it is a new electrified single-track route that branches off from Bubal Station (Gyeonggi Icheon) and connects Chungju~Mungyeong~Gimcheon, major cities in the country's Central inland region. Due to the long route extension, a stepwise project was promoted, and the 1st phase between Icheon (Bubal Station) and Chungju was opened in January 2022, operating KTX-Eum 8 times a day, laying the foundation for railway transportation in the Jungbunaeryuk region. Until now, Icheon and Chungju, the main base cities in the Gyeonggi-Chungbuk region, only had a road transportation network and no railway connecting the two regions. The 2nd phase, the Chungju-Mungyeong section, is under construction with the target of opening in 2024. The Suseo-GyeonggiGwangju section, the starting point, is in the process of detailed design after the basic plan was announced in March 2022, and the Mungyeong-Gimcheon section, the terminal section, is in the basic plan establishment stage. The future Jungbunaeryuk railway will connect Suseo~Icheon~Chungju~Mungyeong~ Gimcheon~Geoje along with the Nambunaeryuk railway between Gimcheon and Geoje. Once each section is completed, it will function as a new inland central main railway from Suseo to Geoje. At that time, Jungbunaeryuk and Yeongnam area high-speed train services will be provided through three branches: the Gyeongbu Line axis, the South Central Inland Line axis, and the Jungang Line axis.

1. Gyeongbu High-speed Railway Line Eonyang Overpass, Introduction of Steel Arch Concrete Composite Girder Bridge for the First Time in Korea and Abroad

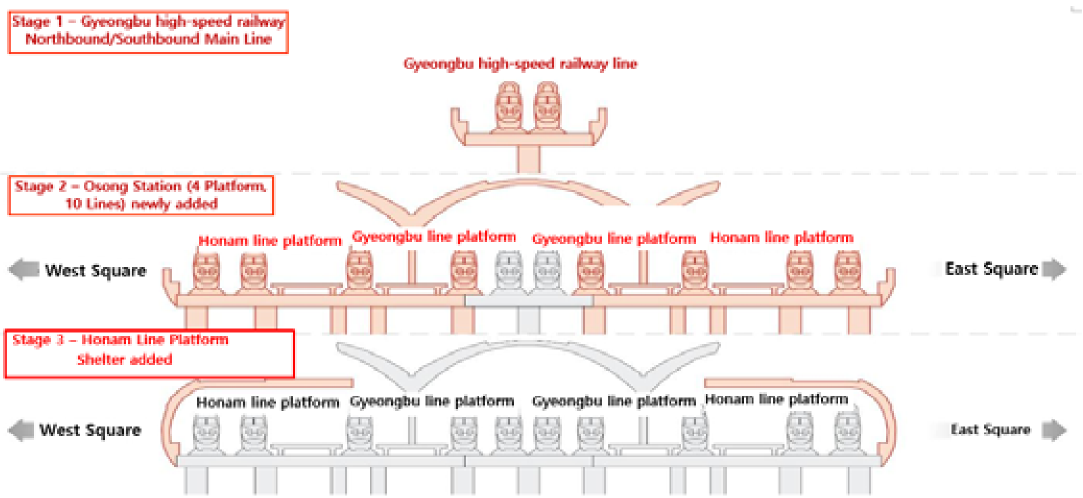
Eonyang Overpass is a steel arch concrete composite bridge located in Eonyang-up, Ulju-gun, Ulsan City. This section requires crossing Ulsan Expressway and National Road No. 24. It was initially designed as a double-track steel composite bridge, but after the Gyeongbu high-speed railway's 2nd phase project began construction in June 2002, the government policy was confirmed to build an additional Ulsan Station in September 2004 during construction, so longitudinal alignment adjustment and Eonyang Overpass have been changed to a station section. A turnout is installed on the bridge, and according to concrete track construction, it was changed to a concrete steel arch bridge with a double arch structure. The temporary construction method for the Ulsan Expressway and National Road No. 24 crossing section connected to the Gyeongbu Expressway was to install vents and temporary girders in advance to avoid interfering with the vehicle flow on the road. The steel arch was lifted with a movable hoist crane on the upper part of the temporary girder, and it was constructed using a method of crossing and placing it while minimizing traffic blocking on the expressway and national highway. For the Eonyang Overpass, the Ulsan Station, which was not in the design, was reflected during construction, making it difficult to complete within the set opening deadline. By introducing the steel arch concrete composite bridge method for the first time in Korea and abroad, we minimized the loss of social overhead costs and resident inconvenience, shortened the construction period, and complied with the opening construction period in 2010.

| Figure 2-1 | Panoramic view of the completion of the Eonyang Overpass of the 2nd stage of the Gyeongbu high-speed railway

Source Korea Rail Network Corporation's railroad site photo

2. Gyeongbu High-speed Railway line Osong Station which is Newly Established on the Bridge on the 300 km/h Operation Line

Osong Station was not initially included in the basic plan for the Gyeongbu high-speed railway's 2nd phase. At the time of the government's decision to build additional midway stations, Gyeongbu high-speed railway's 1st phase (Seoul~Dongdaegu) opened and was a complex construction work that required installing an escape line, platform and grooved roof on the high-speed railway main line bridge, which runs at 300 km/h. The current Osong Station underwent new construction in 3rd phase. In the 1st phase, only two tracks, upper and lower main lines, were installed when the Gyeongbu high-speed railway's 1st phase opened on April 1, 2004. In the 2nd phase, the Osong Station's new construction policy constructed a station facility plan with four platforms and ten lines considering passenger handling of the Gyeongbu high-speed railway line and the Honam high-speed railway line, which will branch in the future. The 3rd phase was the additional construction of the Honam high-speed railway line platform groove roof in the Honam high-speed railway project. For the new Osong Station, construction was impossible during the day when trains ran for safety reasons. Hence, construction had to be carried out at night after train operation ended by blocking the construction. In particular, since the platform was installed on a bridge, it was the most difficult construction work that required precise construction between the tracks to avoid damage to facilities such as tram lines on the operation line by lifting the platform shelter members from the ground with a large crane. Korea Rail Network Corporation, construction companies, and engineering companies worked together to ensure safe opening. Today, it serves as the gateway to Sejong City and Korea's first high-speed railway branch station.



| Figure 2-2 | Gyeongbu high-speed railway's Osong Station phased-construction

Source Illustration by the author

3. Gyeongjeon Line Nakdong-gang River Bridge (Truss Bridge), which is mounted using an Inclined Climbing System + ILM Method

This truss was a large structure with a span length of 70m and a massive weight of up to 700 tons. 'ILM (Incremental Launching Method)' and 'Incline Climbing System' were designed to be manufactured on the ground and installed in the air.

This truss was a large structure with a span length of 70m and a massive weight of up to 700 tons. 'ILM (Incremental Launching Method)' and 'Incline Climbing System' were designed to be manufactured on the ground and installed in the air.

The ILM Method involves assembling truss members by span at the manufacturing site. Then, after being pushed into the air using the Inclined Climbing System, a method of constructing a bridge by pushing it in the route direction using a launching jack. It is easy to respond to disasters such as floods without occupying the river during construction. In particular, the Inclined Climbing System was developed to use an inclined surface to carry moving items when moving into a high-rise apartment. When the inclined lifting device pushes up the truss along a 35-degree inclination angle, the horizontal moving device is a system that horizontally moves the truss to the position of the propulsion axis.

As a result of applying the Truss Inclined Climbing System and ILM Method, compared to the crane construction method, river pollution was minimized, the construction period was shortened by about 15 months, and the resulting indirect cost was reduced by about 1.8 billion won.

| Figure 2-3 | Panoramic view of the Nakdong River Bridge on the Gyeongjeon Line Samnangjin~Jinju double-track railway

Source Korea Rail Network Corporation's railroad site photo

4. Gyeongjeon Line Jillye Overpass (Haro Arch Bridge), which is installed with the Large Block Compression Rotation Method

Among the Jillye Overpass (L=3,085m) section of Gyeongjeon Line No.2-2 Construction Section (Jillye~jangyu) construction, the Haro Arch Bridge, which crosses the Namhae Expressway in three dimensions, was applied for the first time in Korea. It was successfully completed in October 2010. Namhae Expressway, which passes under Jillye Overpass, has eight lanes in both directions, and more than 100,000 vehicles pass through it daily. Initially, the plan was to build a railway bridge by opening a temporary bypass road. Still, it took much work to negotiate with Korea Expressway Corporation, and there was a risk of a major traffic accident due to the poor bypass railway alignment. The arch bridge assembled on the temporary truss could not be constructed using the general launching method of hydraulic pushing. Accordingly, the Haro Arch Bridge rotation launching method was applied to mount the Jillye Overpass Arch Bridge (L=85m). This method creates a bridge outside the Expressway and launches it as the Expressway's upper part. In order to minimize the launching section, a method of launching in a direction perpendicular to the road and then rotating the pier top around the rotation axis and mounting it was applied. As a result, the temporary bent was not installed in the center of the road so that it could be mounted successfully without disrupting vehicle traffic.

Applying Korea's largest large Block Compression Rotation Method to the Arch Bridge under Jillye Overpass shortened the construction period to 6 months without disrupting road traffic. This resulted in a reduction of more than 9% in indirect costs. When considering compensation for indirect losses due to traffic blocking, it gradually reduced by more than 70%. With the development of 'New Technology & New Method,' we now own the patent rights. In 2012, the 'Gyeongjeon Line Jillye Overpass Arch Bridge' received the highest award, the Gold Prize, at the 'Civil Engineering Structure Contest of the Year' hosted by the Korean Society of Civil Engineers.

| Figure 2-4 | Panoramic view of Jinrye Overpass (Haroarch Bridge) on the Gyeongjeon Line Samnangjin~Jinju double-track railway

Source Korea Rail Network Corporation's railroad site photo

5. Jeolla Line Mangyeong-gang River Bridge, which introduced the Concrete Finback Bridge

Mangyeong-gang River is a 675-meter bridge located between Samrye and Dongsan of the Jeolla Line. Construction began in January 2008 and was completed in December 2010, three years later. This bridge was the first concrete finback bridge constructed as a double-track railway bridge. Due to the good prevention of river water pollution, bridge maintenance, and the high rigidity of the structure, the vibration is small compared to the span length, so train drivability and ride comfort are excellent. As a bridge crossing the Mangyeong-gang River, a national river, it was constructed as a combination of a PSC BOX finback bridge and a U-type girder bridge, which is excellent in harmony with the surrounding landscape and economic efficiency. It was established as a local landmark by shaping it into the shape of a tile to harmonize with the surrounding area and have symbolism.

| Figure 2-5 | Jeolla Line double-track train passes through Mangyeong River, with a panoramic view of Mangyeong River Bridge

Source Naver Map Roadview

6. Honam High-speed Railway Line Osong Overpass on which The Train Crosses the Gyeongbu High-speed Railway in Three Dimensions.

As the Honam high-speed railway branches into three dimensions with the Gyeongbu high-speed railway at Osong Station, it was inevitable that the Honam high-speed railway disembarkation would cross to the Gyeongbu high-speed railway upper part. The Osong Overpass steel composite bridge (span length 160 m, 2×80 m) in the Honam high-speed railway No.1-1 Construction Section was ordered as a turnkey construction project. The most crucial issue is precisely controlling the heavy steel bridge (total of 1,600 tons, 600 tons of longitudinal girders x 2, and 400 tons of horizontal girders) and safely installing it on the upper part of the Gyeongbu high-speed railway operation. Therefore, a crawler crane and advanced BIM techniques were introduced. The crawler crane (maximum lifting capacity of 1,350 tons) is equipped with various safety and automatic control devices, allowing the overall working environment and lifting conditions to be controlled. In addition, to ensure the safety of the Gyeongbu high-speed railway, BIM (Building Information Method), a 3D information modeling technique, was introduced. Hence, the steel bridge installation was completed safely without any errors in just three days after starting the steel bridge installation.

| Figure 2-6 | Panoramic view of Osong Overpass, Section 1-1 of Honam high-speed railway

Source Korea Rail Network Corporation's railroad site photo

7. Honam High-speed Railway Line Jeongji Overpass (River Arch Bridge): Expressway Construction without Control

Jeongji Overpass in Honam high-speed railway No. 2-3 Construction Section is a 3-Arch Bridge with a span length of 80+80+80 meters out of 9,315 meters. As it crossed the upper part of the Cheonan~Nonsan Expressway, it was a difficult construction work section with difficulties in ensuring the safety of drivers and vehicles while not interfering with vehicles using the road (45,750/day). The 3-Arch Bridge's upper part is a lower arch bridge (1,268 tons) constructed with three steel arches. The lower part consists of a hollow-type T-type pier at the start and end points and two river piers of 906 tons each, weighing 5,616 tons. ILM (Incremental Launching Method) was applied during the construction of this arch bridge. This method is cutting-edge: lifts the steel arch from the ground using a Hydraulic Jack and then pushes the steel arch back into the jack. For the first time in a domestic railway project, by installing a 4-lane Expressway during vehicle traffic, construction was completed safely without any error by pushing the steel arch horizontally for 64 m at a rate of 4cm per hour. The upper part of the arch bridge symbolizes the Baekje gold crown. The pier top is a sculpture of Jinmyosu (鎭墓獸, a beast-shaped image of a god placed in a tomb). As the gateway to Ganggyeong-eup, Nonsan City has established itself as a local landmark.

| Figure 2-7 | Panoramic view of Honam high-speed railway Section 2-3 overpass

Source Korea Rail Network Corporation's railroad site photo

8. Honam high-speed Railway Line Mangyeong-gang River Bridge: Introduction of Concrete Arch Bridge, Special Bridge

The Mangyeong-gang River Bridge crosses the Mangyeong-gang River in Baekgu-myeon, Gimje City, Jeollabuk-do, in the 3-3 Construction Section of the Honam High-Speed Railway. It is a concrete arch bridge with a span of 1,875 m and has a span length of 65+65+65 m. It was initially designed as an inclined bridge, but the format was changed to become the world's first concrete double arch structure bridge, which was only possible to attempt now. However, by introducing wing-type connection plates and Ramen-style three-dimensional structures, difficulties in construction were overcome and completed successfully. Construction costs were reduced by eliminating steel and PS steel wire use according to the reinforced concrete structure. By reducing maintenance factors such as steel bridge painting, introducing patterns on the arch abdomen and surface, and installing wire mesh, cracks could be prevented.

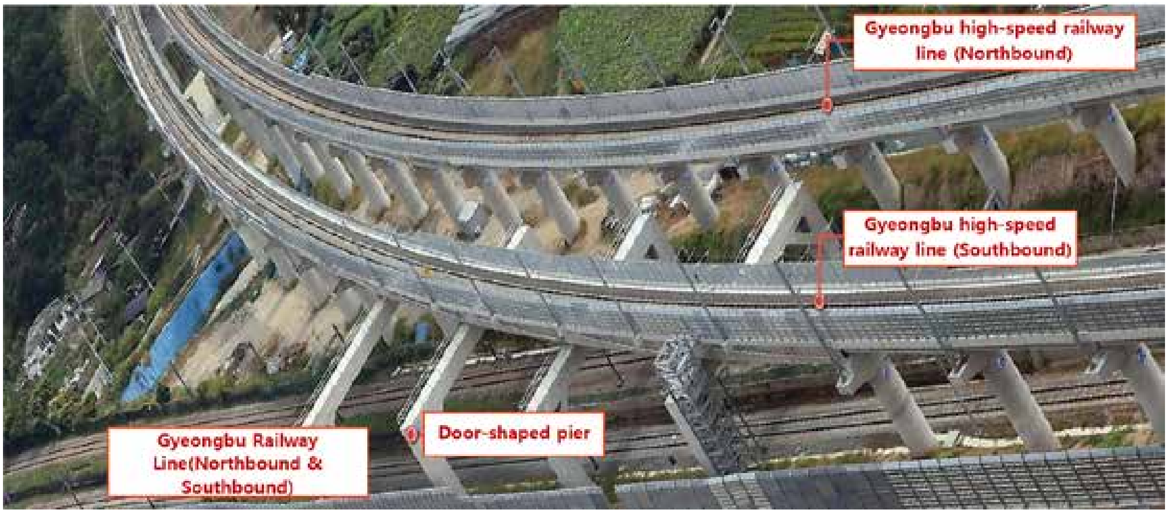
Besides, the red color on the side of the RC arch of the Mangyeong-gang River Bridge symbolizes the sunrise over the Gimje Plain, and by expressing the jewel (ring) symbolizes Iksan City and the flapping wings of an eagle soaring over the Mangyeong-gang River basin; this bridge has established itself as a premium bridge for the Honam High-Speed Railway and received the Gold Prize at this year's「Civil Engineering Structure Contest」 in 2015.

| Figure 2-8 | Panoramic view of the Mangyeong River Bridge in Section 3-3 of the Honam high-speed railway

Source Korea Rail Network Corporation's railroad site photo

9. Gyeongbu High-speed Railway Line Panam 1 Bridge: Portal Pier Heavy Lifting Method Construction

Among the other construction sections of the Daejeon downtown section 6-3 Construction Section roadbed, Panam 1 Bridge (Gyeongbu high-speed railway line disembarkation) is a bridge that crosses the Gyeongbu Line (High-speed railway line) with more than 310 trains running per day. It was difficult construction work that required bridge construction on the upper part of the train that was in operation. However, the initially temporary steel complete staging method could not be constructed due to interference with the feeder during formwork installation. Besides, there was a problem that it could not be applied because there is a risk of electric shock when assembling and disassembling jack support. In order to ensure the safety of passengers without interfering with train operation, construction was changed to the 'Hoist + Heavy Lifting Method'. This method involves pre-fabricating a portal pier on the ground, lifting it into the air with a hoist, and pushing it to the side to mount the dock on the upper section of the Gyeongbu Line railway in operation. By changing the temporary steel complete staging method to the Hoist + Heavy Lifting temporary method, the construction period was shortened from the original 240 days to about 135 days, and the safe operation of the Gyeongbu Line train was secured.



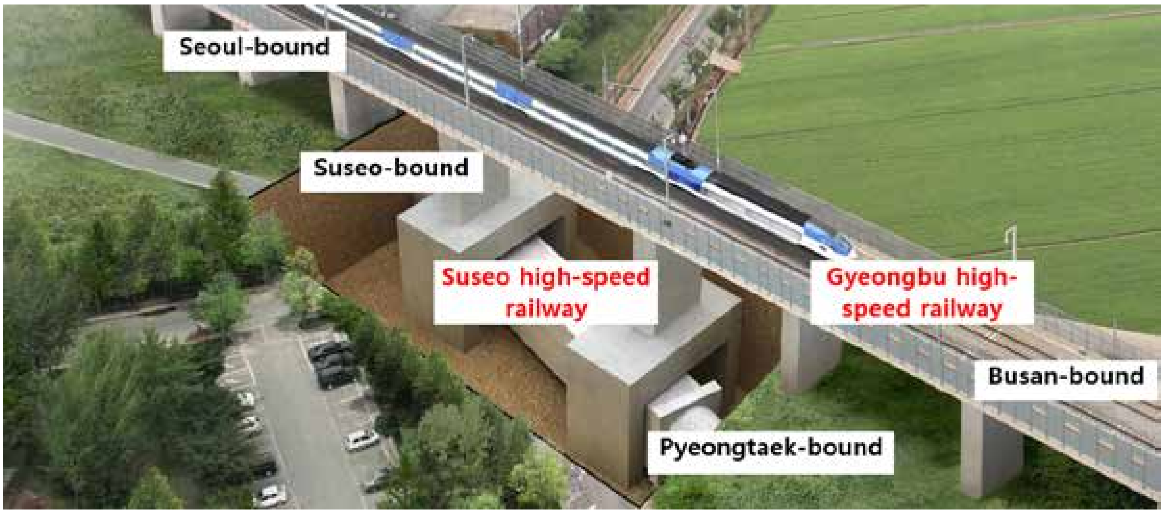
| Figure 2-9 | Panoramic view of the gate-shaped pier of Panam 1 Bridge in the Daejeon city center section of the Gyeongbu high-speed railway

Source Naver Map Roadview

10. Suseo High-speed Railway Line Tongbok Tunnel: Difficult Construction to Pass Directly under the Paengseong-1 Overpass of the Gyeongbu High-speed Railway

As the Suseo High-Speed Railway route plan is to establish a new route between Suseo and Pyeongtaek and to share the Gyeongbu High-Speed Railway line between Pyeongtaek and Osong in the Pyeongtaek City section, it is necessary to build the Suseo high-speed railway line into a single line parallel to the Gyeongbu high-speed railway line and connect it to the Gyeongbu high-speed railway line mainline section in each direction. As the two routes are three-dimensional, the Suseo high-speed railway line (Northbound) passes through the tunnel through the lower part of the Gyeongbu high-speed railway line Paengseong-1 Overpass. Therefore, it was the most challenging construction work as the Tongbok Tunnel had to be constructed using a cut-and-cut method after cutting the Paengseong-1 Overpass pier piles. The Trench Cut Method was applied for the Tongbok Tunnel construction. To ensure the safety of the operation line, the Gyeongbu high-speed railway line Paengseong-1 Overpass, at the bottom of the bridge, an earth retaining facility, hydraulic jack automation system, real-time automation measurement, and monitoring were built.

The automatic hydraulic jack system, which is the core of these, is an automatic system that collects and reads measurement and survey data on the structure in real-time and immediately and automatically returns it to its original state when subsidence or displacement occurs. The method of passing under a high-speed railway running at 300 km/h is the first of its kind in the world, and as a result, it has raised Korea's tunnel technology to a higher level.

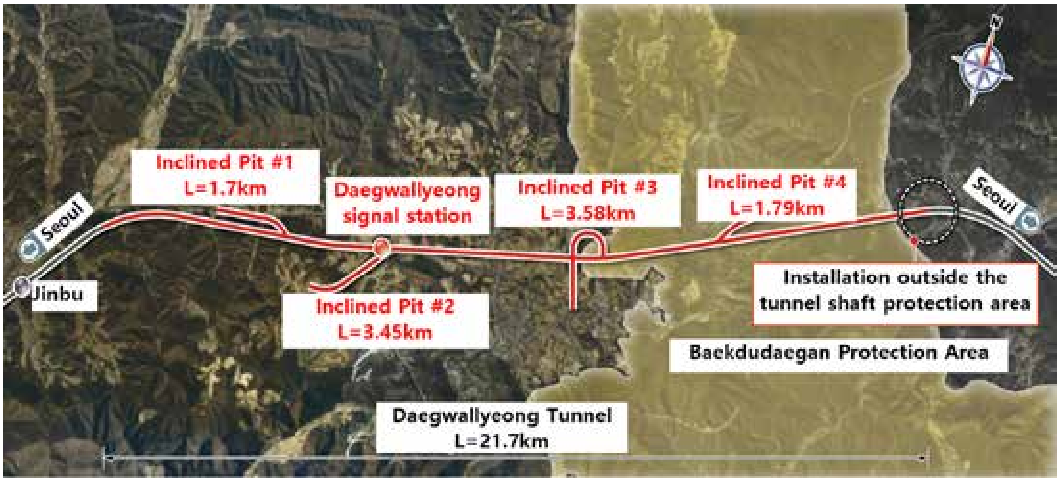


| Figure 2-10 | Current status of Suseo high-speed railway Tongbok Tunnel

Source Korea Rail Network Corporation's press release

11. Gangneung Line Daegwallyeong Tunnel: Korea's Longest Mountain Tunnel Constructed Using Eco-friendly Methods

Because Pyeongchang and Gangneung have a significant elevation difference (440 m), when connecting the two areas with a longitudinal slope of 12.5‰, a loop-shaped route occurs, which causes the route to be longer than 30km and the project cost to increase, a straight route plan was established by sharpening the longitudinal slope to 25‰. Due to route straightening, the Baekdudaegan section had to be passed through a long tunnel due to its topographical characteristics. This tunnel is the longest in Korea (L=21.7km), passing through a mountainous area, and four inclined tunnels were installed in the middle for disaster prevention and to shorten the construction period. Daegwallyeong Signal Station was constructed at the tunnel's midpoint to enable a train meeting and evacuation in case of an emergency. In the upper part are many temperature-controlled facilities, such as pension houses and livestock barns. Therefore, noise and vibration were minimized through sequential blast using pre-large hole boring and an electronic detonator instead of general blasting. Cut-off grouting was constructed to prevent damage due to groundwater leakage. In addition, considering the terrain characteristics passing through Baekdudaegan, a first-class area in both ecology and nature, the tunnel gates area was installed outside the protected area and extended forward as much as possible to minimize environmental damage, such as slopes. From the initial stage of construction, social conflicts were resolved by forming and operating the 'Baekdudaegan Environmental Advisory Group' together with the Green Korea United Baekdudaegan Conservation Society.



| Figure 2-11 | Floor plan status of the Daegwallyeong Tunnel, the longest in Korea, on the Gangneung Line

Source Written by the author based on Naver topographic map

12. Gangneung Line: Introduction of the World's first 4G Korea-type LTE-R Wireless Telecommunication Technology

Meanwhile, the domestic wireless telecommunication system used the VHF method in general railways, and TRS-ASRTO (Gyeongbu high-speed railway line) and TRS-TETRA (Honam high-speed railway line) in high-speed railways, by introducing different methods from overseas for each route. The world's first LTE-R wireless telecommunication system was introduced and constructed on the Gangneung Line. LTE-R is a Korea-type wireless telecommunication system and is the world's first wireless telecommunication system that develops 4th generation mobile telecommunication technology suitable for railway operation and can provide various application services such as train control system signal transmission and high-speed data and video transmission. Through LTE-R, high-quality audio service and high-capacity data and video service of up to 100 Mbps have become possible, even in trains running at high speeds. This makes it possible to unify the various train wireless telecommunication systems used in Korea, eliminating the hassle of crew members changing the telecommunication system for each section. In addition, through large-capacity data transfer, train operation and maintenance work can be streamlined by providing integrated information on train stations and train status. Thus, it has become possible to offer train users a higher level of high-definition video service inside the train.

13. Jungang Line Namhan-gang River Bridge: Danyang-gun Landmark in the Shape of Dodamsambong

Namhan-gang River Bridge (L=480 m), a Danyang-gun landmark located in the No. 1 Construction Section section of the Jungang Line Dodam~Yeongcheon double-track train Project, is one of Danyang Palgyeong. Designated as Scenic Beauty No. 44, it symbolizes the winding water streams of the Dodam Sambong and Namhan-gang Rivers, maximizing the beauty of the bridge shape through colorful top and bottom directions and applying optimal proportional ratios. In addition, a new concept, a curved truss + arch composite bridge, was selected to harmonize with Danyang's beautiful natural scenery. The Namhan-gang River Bridge's application method is a design bridge that harmonizes with the surrounding skyline. By expanding the main span (L=120 m), the number of piers in the river was minimized to allow for the passage of ships such as cruise ships in the future. The plan was designed to maximize the sense of openness and preserve the river environment. Looking down from Cheonju-bong 'Manchenha Skywalk,' one of the Danyang-gun tourist attractions, you can see Danyang Station, the new and old Namhan-gang River Bridge, and the Danyang-gun cityscape at a glance.

| Figure 2-12 | Panoramic view of the Namhangang Bridge on the Dodam-Yeongcheon double-track railway

Source Korea Rail Network Corporation's railroad site photo

Section 6 High-speed (& Semi-high-speed) Rrailway's Impact on Railway Construction

High-speed railway operation not only brought about many changes across Korea's economy, society, culture, and tourism but also brought about many changes in Korea's economy, society, culture, and tourism but also brought innovation to the railway industry as a whole, including full-scale construction technology development in each field and development of domestic production of parts and supplies. The positive impact of introducing high-speed railways on railway construction is as follows.

First, the PM (Project Management) system was introduced to manage railway construction projects systematically. A railway construction project has the characteristic of constructing optimal infrastructure through organic interfaces between roadbed, track, architecture, and E&M and harmonizing it with vehicles and operations. Before the introduction of the high-speed railway, it was limited to simple process management through functional organization for each detailed project. However, a PM system based on the matrix organization was introduced, making efficient and systematic construction project management possible.

Second, there is a change in perception regarding quality control of structures such as bridges and tunnels. high-speed railways run at high speeds, so even minor defects can lead to major accidents; therefore, tunnel shotcrete, lining concrete, etc., were produced and procured in-house at the on-site batcher plant, and even during construction, thorough quality control was implemented at each material entry stage, construction stage, and post-construction stage. This led to introducing a systematic quality control system in the general railway construction project.

Third, a convergence design of vehicles and roadbeds was introduced. In the early stages of High-Speed Rail Construction, due to a lack of experience with the interaction between vehicles and roadbeds when trains operate at high speeds, design speeds of 150 km/h or less dynamic problems on bridge roadbeds, which had not been considered in general railways, have emerged. So, a high price was paid by dismantling the upper part of the I-type girder of the already constructed Gyeongbu high-speed railway bridge and replacing it with a highly rigid box girder.

Fourth, innovation in track technology, such as branching machines. As a result of efforts to develop track technology and localize it to supplement the problems that arose due to the introduction of concrete tracks throughout the Gyeongbu high-speed railway's 2nd phase (Dongdaegu~Busan), track supplies such as rail fasteners and high-speed turnouts, which had been imported entirely from foreign countries and had many difficulties in maintenance, were domestically produced and commercialized. Additionally, after the Gyeongbu high-speed railway's 2nd phase of construction, concrete tracks were adopted instead of gravel tracks in most construction projects, dramatically reducing track maintenance costs, and we have domestically produced the PST (Precast Concrete Slab Track) Method. This factory-made concrete track complements the problems of the cast-in-place concrete path.

Fifth, technology development and localization in the system field. During the construction of the Gyeongbu high-speed railway's 1st phase (Seoul~Dongdaegu), most of the technology, including tram lines, telecommunications, and signals, was transferred from France. Afterward, we accelerated technology development and localization in the E&M field. We did our best for commercialization through test construction, including local production of high-speed catenary components such as tension control devices, LTE-R telecommunication system development, and KTCS (Korea Traffic Control System) Korea-type signal system development. In addition to high-speed railway routes, it is being sequentially introduced to high-speed and general railway routes that have operated since the past.

08

Development of High-speed Rail Vehicles in Korea

Section 1. Ministry of Science and Technology's High-speed Train Technology Development Strategy Establishment Study (1988~1989): The First High-speed Railway Research Project

Section 2. Ministry of Science and Technology's 『High-speed Train Technology Development Research/Opportunity Investigation Project』 (1993~94) and 『High-speed Train Design Technology Development』 Project (1994~1996): Measures for Alstom's Insufficient Technology Transfers

Section 3. Korea-type High-speed Train(KTX-Sancheon) Development (1995~2007)

Section 4. Decentralized High-speed Train Development Project (HEMU Development Project)

03 Development of High-speed Rail Vehicles in Korea

Here, we want to mention the process of Korea developing independent R & D and Korea-type high-speed railway vehicles through transferring high-speed railway technology.

Section 1 Ministry of Science and Technology's High-speed Train Technology Development Strategy Establishment Study (1988~1989): The First High-speed Railway Research Project

Research on Korea's high-speed railway began with an unexpected opportunity. In 1987, West Germany - Federal Ministry of Research and Technology (BMFT; Bundes ministerium flir Forschung und Technologie) Minister visited Korea and signed an MOU (Memorandum of Understanding) with Korea's Ministry of Science and Technology (MOST) Minister. For the two countries to promote cooperative research, "Mass Ground Transportation Research (MGTR)" was included as one of the cooperative research. Although the Ministry of Science and Technology understood MGTR to be subway research, in 1988, West Germany proposed to begin joint research with Korea on high-speed trains and maglev trains. West Germany would have proposed joint research at a strategic level to sell ICE (Inter-City Express) or high-speed maglev train (Transrapid) to Korea. The Ministry of Science and Technology sensed this intention and is said to have politely declined under the pretext of an investigation study. It was a wise response under the circumstances at the time.

In July 1988, Dr. Lee Jong-won, who was a mechanical research coordinator in the Ministry of Science and Technology, asked Dr. Lee Hae to conduct "Strategy Establishment Research for High-Speed Train Technology Development"(1) for technology investigation on high-speed trains and maglev trains as a national research project. At the time, Dr. Lee Hae was a research fellow (and former director) at the Structural Analysis Laboratory (Director, Song Dal-ho) at the Korea Institute of Machinery & Materials (KIMM) (Changwon). Considering the broad academic field of high-speed trains and maglev trains, Dr. Lee Hae decided that the investigation could

(1) Ministry of Science and Technology et al., (1989). Research study to establish high-speed rail technology development strategy. UCN240-1282.C, Korea Institute of Machinery and Materials

not be conducted by the KIMM Structural Analysis Laboratory alone, so he sought cooperation from the Korea Electrotechnology Research Institute (KERI). KERI's then-director, Ahn Woo-hee, readily gave permission. In addition, the Korea Institute of Science and Technology (KIST), railway vehicle manufacturers Hyundai Precision and Daewoo Heavy Industries, and electric motor manufacturer Hyosung Heavy Industries Corporation also participated in this investigation project. Samsung Electronics and Geumseong Industrial Systems, which were interested in railway vehicle technology construction and the high-speed train construction project, were the only railway vehicle engineering companies at the time to participate. A High-Speed Train Research Working Committee with directors and practitioners from organizations that promised cooperation was formed. Dr. Lee Hae invited working committee members from KIST and the industry through his personal capabilities. There was no compensation for participation, and overseas business trips were to be borne by each affiliated organization. Afterward, the actual project implementation was carried out by Dr. Lee Hae. Song Dal-Ho led it.

We investigated the current status of research institutes related to railway vehicles at home and abroad and the technology status of foreign high-speed trains, such as Japan's Shinkansen, France's TGV, and West Germany's ICE, and maglev trains, such as West Germany's Transrapid and Japan's MLU (Magnetic Levitation Unit), were also investigated. A technology tree for high-speed and maglev trains was created based on this. Additionally, 14 R&D projects (High-speed train, seven maglev trains) were derived, and a project summary was written for each research project.

Ultimately, nine items regarding R&D were proposed; among them, the notable one was: "Selecting a high-speed train model is important, but local production and technology independence is even more important. When selecting a model, technology transfer must be a top priority." The suggestion was to consider technology transfer when selecting a model. This suggestion was later actually reflected. In other words, the government ordered the Korea Transport Institute (KOTI) to conduct a technology investigation on the Gyeongbu high-speed railway construction on July 15, 1989. In order to carry out this service, KOTI established the "Gyeongbu High-speed Train Construction Preparation Team," in which railway-related professional organizations participate. Manager Han Gyu-Hwan of Hyundai Precision, participated in this construction preparation group, and Manager Han also participated in KIMM's technology investigation project. Therefore, Manager Han included technology transfer as one of the four evaluation factors for model selection in the request for bidding for railway vehicles to be operated on the Gyeongbu high-speed railway prepared by the construction preparation team. Including technology transfers in the bid evaluation was a retrospective idea.

Section 2 Ministry of Science and Technology's 『High-speed Train Technology Development Research/Opportunity Investigation Project』 (1993~94) and 『High-speed Train Design Technology Development』 Project (1994~1996): Measures for Alstom's Insufficient Technology Transfers

From then on, the Ministry of Science and Technology intermittently supported the high-speed train technology research project. In particular, the 1993 "High-speed Train Technology Development Research/Planning Investigation Project"(2) and the 1994 "High-speed Train Design Technology Development"(3) project, which was carried out as a result, deserve attention. These research projects resulted from the selection of the type (model selection) of the high-speed train to be introduced during the construction of the Gyeongbu high-speed railway in 1992-93. Technology transfers were considered important in model selection as one of the four major evaluation factors. However, when it was predicted that the technology transfer plan of Alsthom, which was selected as the preferred bidder, would be insufficient, researchers at the government-funded research institute who participated in model selection suggested that the Ministry of Science and Technology engage in technology development, so Ministry of Science and Technology began high-speed train technology investigation and research planning in October 1993. In mid-1994, technology investigation and research planning were completed by creating a research plan for the 『High-speed Train Design Technology Development』 Project. The Ministry of Science and Technology launched the 『High-speed Train Design Technology Development』 Project in a very scaled-down form at the end of 1994, worth 2 billion won, due to budget issues.

In the original planning project, the projects planned to be launched in 1994 were 52 projects worth 6.66 billion won. The research fund was slightly less than 2 billion won and needed to be increased to start all projects. So, as a last resort, considering the importance of the projects, it was decided to provide research funds only for 12 basic technology projects.

In the 『High-speed Train Design Technology Development』 Project, major specifications (draft) of Korea-type high-speed trains were created, as shown in Table 3-1.

(2) Seongbin Lim et al., (1994). High-speed rail technology development research planning and survey project. Korea Institute of Machinery and Materials.

(3) Sehun Yang et al., (1994). Strategy for localization of high-speed rail-related technologies. Production Technology Research Institute.

| Table 3-1 | Main Specifications of Korea's High-speed Railway (draft)

Items	Korea-type high-speed Train's Feature	TGV-K's Feature
Compatibility to TGV-K	(1) Power supply system (25 kV, 60 Hz)	←
	(2) Power car type train (Push-Pull Type)	←
	(3) Articulated Bogie	←
Korean Style	(1) Maximum driving speed: 350 km/h	(1) Maximum driving speed: 300 km/h
	(2) Frontal region: Unique design	(2) Frontal region: France design
	(3) Carriage body: aluminum extrusions	(3) Vehicle body: mild steel
	(4) Electric motor: Induction Electric motor adopted	(4) Electric motor: Synchronous Electric motor
	(5) Brake system added: Eddy current brake	(5) Brake system: Mechanical braking + Regenerative braking
	(6) Tunnel Micro Pressure Wave Measures: Pressurization system	(6) Tunnel Micro Pressure Wave Measures: Vent system

In April 1996, it was confirmed that 『High-speed Train Technology Development』 would be carried out as a G7 Project. The 『High-speed Train Design Technology Development』 Project, carried out with the support of the Ministry of Science and Technology since December 1994, was finally completed in December 1996 after completing the 2nd year of research. Dr. Song Dal-ho, who was the general manager of the 『High-speed Train Design Technology Development』 Project, insisted that the research projects carried out in the 『High-speed Train Design Technology Development』 Project be inherited by the G7 Project, but this was not accepted. To that extent, the research funds invested so far were wasted, and researchers already immersed in research were excluded. This was because, in the hegemony battle between the Ministry of Construction and Transportation and the Ministry of Trade, Industry, and Energy over the G7 Project, the Ministry of Science and Technology's influence had no effect.

However, the specification (draft) of a Korea-type high-speed train, Table 1, was inherited as it is in the G7 Project. This was because the High-speed Train Specification (draft) in Table 1 was so clear that it could not be changed.

Section 3 Korea-type High-speed Train(KTX-Sancheon) Development (1995~2007)

(1) Research Planning to Promote as the G7 Project

In 1992, the government promoted the Advanced Technology Development Project (G7 Project[(1)]) with the Ministry of Science and Technology as the overall department. Starting the 2nd phase in May 1995, it was decided to actively discover and promote new projects that align with changes in domestic and international technology, economy, and environment[(2)]. In early February 1995, Dr. Song Dal-ho recognized that the Ministry of Science and Technology was inviting a new G7 Project. He proposed to the Ministry of Construction and Transportation and the Korea High-Speed Rail Construction Corporation (now referred to as 'Construction Corporation') to promote high-speed Train Technology Development as an additional G7 project under the Ministry of Construction and Transportation. However, the Ministry of Construction and Transportation and the Construction Corporation refused, saying there was no need to do so as all technology would be transferred. Accordingly, the Ministry of Trade, Industry and Energy and the Korea Institute of Industrial Technology recommended the 『High-speed Train Technology Development』 Project as a G7 project, as shown in Table 2, under the pretext of developing high-speed trains for overseas export.

| Table 3-2 | Application for high-speed rail technology development as a new candidate project

Category	Project name	Study Topic	Hosted by	Related to	Remarks
Product Technology Development	High-speed Train Technology Development (1995~2001)	Korea-type high-speed Train Technology Development & Related Parts Technology Development (Over 300 km/h)	Ministry of Trade, Industry and Energy	Ministry of Science and Technology; Ministry of Construction and Transportation	

#: The new candidate project research planning RFP is described as "300 km/h class", and at the research planning briefing held on July 26, there was also a focus on local production of parts for 300 km/h high-speed rolling stock. Therefore, in reality, it was understood as a "300 km/h high-speed train."

Source Ministry of Science and Technology et al., (1995). Guide to Research Planning Projects for New Candidate Projects of G7 Phase 2.

(1) G7 means the meeting of finance ministers from five countries, including the United States, the United Kingdom, France, West Germany, and Japan, that gathered to discuss measures against the first oil crisis in 1973 was promoted to a summit during the second oil shock (1975). With the joining of Italy (1975) and Canada (1976), the number of countries became 7, which refers to the most advanced countries. The G7 project is a national research and development project that was promoted across all ministries in 1992 with the goal of upgrading Korea's science and technology level in the semiconductor, transportation, communications, environment, and energy fields to the level of G7 countries. The official name was the Leading Technology Development Project, and the overall ministry was the Ministry of Science and Technology. A total of 18 projects were promoted as G7 projects. This means that there were 18 G7 projects. G7 was organized by seven government ministries, including the Ministry of Science and Technology, and about 20,000 technical personnel from research institutes, universities, and companies participated. It is known to be the largest research and development project since the founding of the country, with a budget of approximately 4.6 trillion won.
The reason why the "High-speed Rail Technology Development Project" (High-speed Rail Project) hosted by the Ministry of Construction and Transportation is called the G7 project is because the high-speed rail project is the only G7 project managed by the Ministry of Construction and Transportation, so there is no room for confusion.

(2) Ministry of Science and Technology et al., (1995). G7 Phase 2 new candidate project research planning project guide.

Minister Oh Myoung of the Ministry of Construction and Transportation was taken aback by this and said that the Ministry of Construction and Transportation would also promote the 『High-speed Train Technology Development』 Project and an application was made to the Ministry of Science and Technology. He also summoned the head of the Ministry of Construction and Transportation Park Seong-pyo High-speed Railway and the head of the Construction Corporation Lee Woo-Hyeon vehicle division. He ordered the Ministry of Construction and Transportation to do its best to take charge of the 『High-speed Train Technology Development』 Project. As a result, the Ministry of Trade, Industry and Energy and the Ministry of Construction and Transportation decided to lead the 『High-speed Train Technology Development』 Project. Accordingly, the Ministry of Science and Technology conducts research planning for the 『High-speed Train Technology Development』 Project competitively with the Ministry of Trade, Industry and Energy and the Ministry of Construction and Transportation and decided to evaluate the results. The plan was to conduct the project according to an excellent research plan (draft). However, the evaluation was conducted by the Ministry of Trade, Industry and Energy, which recommended the additional project. Research planning began on August 1 of the same year, and two months were given.

The Ministry of Construction and Transportation and Construction Corporation's affiliated organizations needed more experts to plan large-scale national research projects. Construction Corporation's R&D headquarters closed at the end of April 1994, and the Railway Technology Institute under the Korean National Railroad closed at the end of June of the same year. The Korea Railway Industry Technology Institute (Korea Railroad Research Institute), which replaced the Railway Technology Institute, was established on July 16, 1994; however, it did not yet have the skills to conduct research planning for large-scale national research projects. Ministry of Construction and Transportation and Construction Corporation asked KIMM and Dr. Song Dal-ho to conduct research planning. Construction Corporation created a research planning project by providing administrative support such as research planning and office budget. The project manager was Lee Woo-hyeon, head of the vehicle division, but research planning was left to Dr. Song Dal-ho with full corporation.

The research plan (draft) prepared by Construction Corporation and Korea Institute of Industrial Technology was submitted to the Ministry of Trade, Industry and Energy in early October. In the evaluation of competitive research plans conducted on October 20 of the same year, although the evaluation agency was the ‘Ministry of Trade, Industry, and Energy’, Construction Corporation's research planning (draft) was selected as overwhelmingly superior (10 good drafts for Construction Corporation, one draft equal, 2 technology good for Korea Institute of Industrial Technology). Korea Institute of Industrial Technology's research planning (draft) was judged to have inappropriate research objective settings and problems with commissioning tests. Nevertheless, the Ministry of Trade, Industry, and Energy later filed a complaint, and a drawn-out controversy ensued. The Ministry of Construction and Transportation and the Construction Corporation, which needed more communication with the research community, could not stick to their research plans (draft). In the end, even the Blue House's Senior Secretary to the President for Economic Affairs was involved, and the Ministry of Trade, Industry and Energy and the Korea Institute of Industrial Technology had to be accepted as joint cooperative organizations as the responsible ministry and general research organization for the research project, respectively. Instead, an agreement had to be reached where the Korea Institute of Industrial Technology would be in charge of the major “vehicle system” project, and the Construction Corporation would act as a cooperating organization. The Ministry of Construction and Transportation and the Construction Corporation maintained their role as the supervising ministry and overall supervising agency. The overall justification was gained by giving up the lead organization for the major “vehicle development” project, and the practical result was given away. It can be said that the original sin was that the Ministry of Construction and Transportation and the Construction Corporation had no interest in R&D and neglected technology development.

In early 1996, through an inter-ministerial agreement, the Korea Institute of Industrial Technology decided to participate as a cooperating organization in the overall management organization, and joint research planning was immediately initiated. Accordingly, a joint research planning schedule was agreed upon, as shown in Table 3. Construction Corporation and the Korea Institute of Industrial Technology planned to cooperate and complete the joint research planning in early March. In April, the Ministry of Science and Technology planned to confirm the 『High-speed Train Technology Development』 Project as a G7 Project.

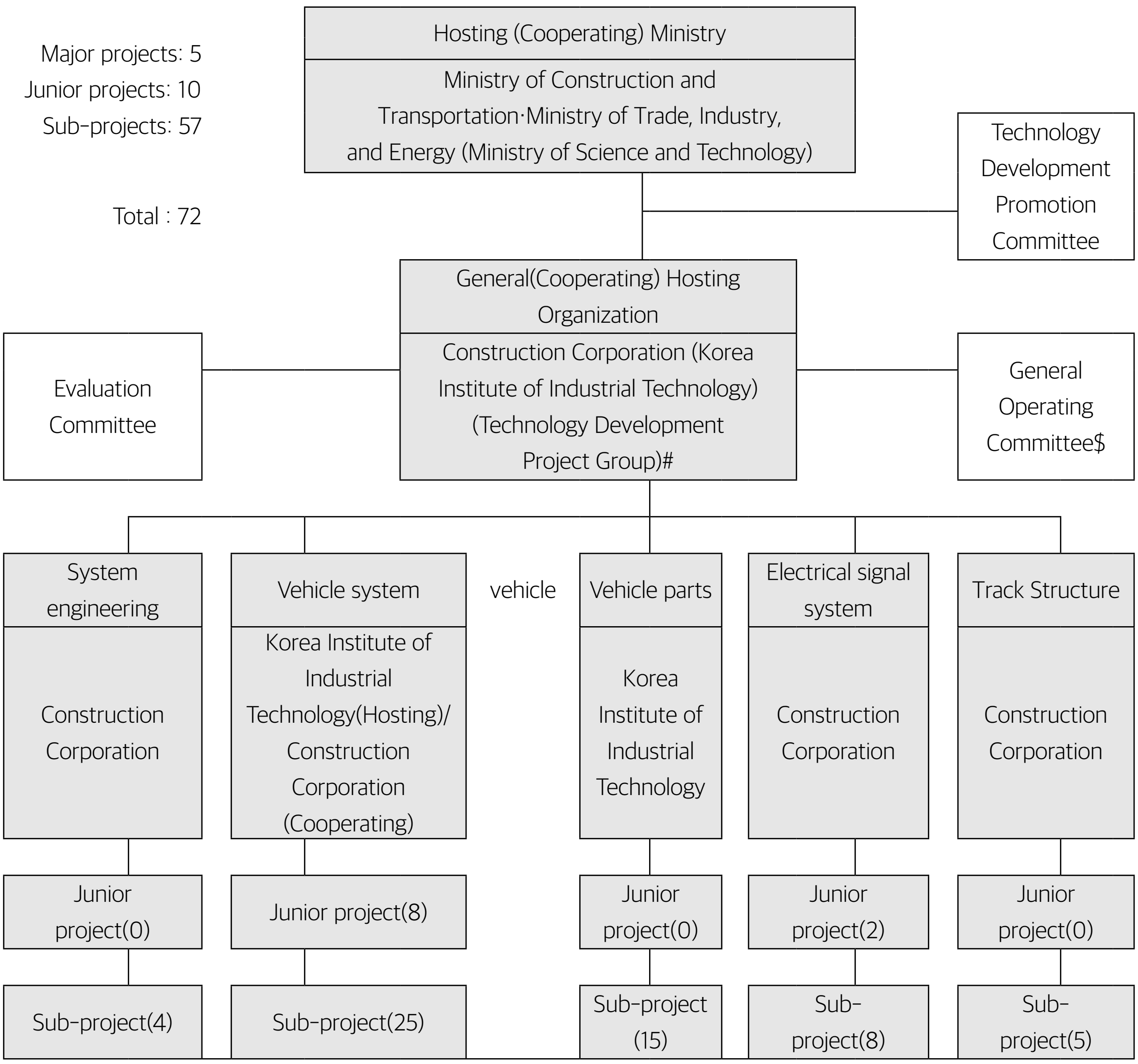
| Table 3-3 | Joint research planning schedule plan

Date	Briefs
1.18.	Research planning team personnel kick-off meeting
1.22. ~ 1.27.	Work coordination and discussion on research planning (budget/planning/basic plan for major categories)
1.29. ~ 2.10.	Research planning report writing, report cover review (1.29. ~ 2.3.)
2.08.	Holding an advisory meeting (Construction Corporation)
2.12. ~ 2.13.	Inter-ministerial consultation (Ministry of Construction and Transportation, Ministry of Trade, Industry and Energy, Ministry of Science and Technology)
2.14. ~ 2.16.	Research planning report printing
2.17.	Research planning report submission (Construction Corporation Plan)(3.05. Ministry of Science and Technology submission deadline)
3.14.	Evaluation Subcommittee on Evaluation
3.22.	Evaluation of planning advisory council
Early April.	Advanced Technology Development Council (Shipping Council) # held

A consultative body for promoting the G7 Project, composed of director-level public officials from relevant ministries and industry-academia-research experts at the head level of affiliated organizations, organized by Ministry of Science and Technology (Chairman: Ministry of Science and Technology R&D Coordination Director)

Looking at the results of joint research planning, the main characteristics of Korea-Type High-Speed Trains were adopted, as shown in the specification (draft) in Table 1. In addition, the Korea-Type High-Speed Train Technology Development promotion system was proposed as previously agreed upon, as shown in Figure 1. In other words, the plan is to have a cooperative organization in the supervising ministry, general supervising organization, and supervising agency of the vehicle system major project.

In addition, the Technology Development Project Team was established as the overall supervising agency and comprises the Construction Corporation, the Korea Institute of Industrial Technology, and an industry-academia research consortium. It was questionable whether a consortium would be possible. Additionally, the plan is to have an independent steering committee for each major project. The general management organization has a general steering committee, but the general steering committee and the five major project steering committees are independent. There would be no solution if they couldn't cooperate with each other.



Composed of Construction Corporation, Korea Institute of Industrial Technology, and an industry-academia-research consortium.
$ Just as the general management organization has a general steering committee, the 5 major projects have a steering committee for each major project. The general management committee of the general organization was independent of the major project steering committee.

| Figure 3-1 | G7 Project Implementation System of Joint Research Planning (draft)

Source Lee, woohyun, (1996). Leading Technology Development Project: High-speed Rail Technology Development, (organized by)Korea Train Express, (cooperated with) Korea Institute of Industrial Technology. pp.220-225,p.274.

The 6-year research period (1996-2002) was divided into the 2nd phase, and the final objective, objectives by stage, and performance details were presented in Table 4. Since the research scope includes systems other than vehicles, there are a total of 11 technology contents that present objectives for each stage, but only three are shown in Table 4.

| Table 3-4 | Jointly planned research project objectives, goals and implementation details by research stage

<table>
<tr><th>Final Objective</th><th colspan="2">Setting the final objective of the main specifications (draft) in Table 1 as the core technology specification</th></tr>
<tr><td rowspan="2">Development details#</td><td colspan="2">Objective by research stage</td></tr>
<tr><td>1st phase (1996 ~ 1998)</td><td>2nd phase (1999 ~ 2001)</td></tr>
<tr><td>System engineering technology</td><td>- high-speed Train System specification determination and concept design
- high-speed train performance analysis technology development
- System interface development</td><td>- Commissioning test
- Establishment of a high-speed train system evaluation system
- Improve high-speed train system reliability
- Building a foundation for independent technology development</td></tr>
<tr><td>Vehicle system engineering technology</td><td>- System concept design
- Securing the basis for core analysis and design technology and applying it to the detailed design of the prototype</td><td>- System evaluation technology
- Complete core analysis and design technology and ensure reliability</td></tr>
<tr><td>Prototype development technology
- Powered car,
- Powered passenger car
- Passenger car,
- Bogie</td><td>- Prototype system engineering
- Concept & detailed design
- Production of the conceptual model</td><td>- Optimization design
- Prototype car production
- Prototype performance test</td></tr>
</table>

Regarding the development contents, only three were shown here. In reality, the stage-specific objectives are additionally specified for the following: parts management and evaluation technology development; propulsion system development; vehicle diagnostic processing system development; braking system development; signal control system development; railway comprehensive information system development; tram line and power supply system development; track structure development

Source (Press release) Ministry of Science and Technology (R&D Coordination Office), (1995). the Second Stage New Task and Implementation Plan for the Leading Technology Development Project, November 1995. pp.219-220

The annual budget details of the G7 Project were as shown in Table 5. The total research cost required was 287.4 billion won, of which more than half, or 159.3 billion won, was planned to be invested in major project vehicle system development.

| Table 3-5 | Total joint planning research budget

No.	Major Project Name	Hosting(Cooperating)	'96	'97	'98	'99	'00	'01	Total(100 Million₩)
I	System Engineering Technology Development	Construction Corporation	14	30.3	32.8	50.3	56.3	49.3	233
II	Vehicle system development	Korea Institute of Industrial Technology (Construction Corporation)	73	375.0	374.0	337.0	326.7	107.3	1,593
III	Vehicle parts development	Korea Institute of Industrial Technology	15	71.0	99.0	75.5	30.5	9.0	300
IV	Electrical signal system development	Construction Corporation	22	92.4	94.5	101.2	86.1	51.8	448
V	Track Structure Technology Development	Construction Corporation	16	32.6	45.7	65.8	68.6	71.3	300
Total			140	601.3	646.0	629.8	568.2	288.7	2,874

Source (Press release) Ministry of Science and Technology (R&D Coordination Office), (1995). the Second Stage New Task and Implementation Plan for the Leading Technology Development Project, November 1995. p.299

The above joint research plan (draft) was passed without revision at the ministry consultation, evaluation subcommittee, planning advisory meeting, and Shipping Council. Therefore, it was confirmed as the research plan of the G7 Project.

(2) G7 Project Launch and Initial R&D Confusion

An agreement was reached with the Ministry of Trade, Industry, and Energy to carry out the project. The process of establishing administrative systems and procedures to manage, operate, and supervise project execution could have been smoother and was completed in August. That is, 『High-speed Train Technology Development Project Joint Operation Guidelines』 (August 1996, Ministry of Construction and Transportation·Ministry of Trade, Industry and Energy). The appointment of a Project Leader was even more difficult. In early 1996, there was a verbal agreement that the Construction Corporation would recommend the Korea Institute of Industrial Technology to the Project Leader and the Deputy Leader. Accordingly, Construction Corporation recommended Dr. Lee Hae[(3)] of KIMM, but the Korea Institute of Industrial Technology opposed it. Afterward, several

(3) Dr. Lee Hae served as the Director of the Korea Institute of Machinery and Materials (1985-1988) after serving as the Coordinator of Mechanical Research at the Ministry of Science and Technology. At the request of the Ministry of Science and Technology, he served as the research director for the "High-speed subway technology development research" project (1988-1989), and at the time, he was working as a research fellow at the Korea Institute of Mechanical Engineers.

people were mentioned, but they opposed each other and were ultimately not appointed. Entering December 1996, the project had to be launched within the year due to a budget issue in the National Assembly. Director Lee Woo-Hyeon, who was in charge of the Construction Corporation research planning project in competitive research planning, decided to take on the role of Project Leader on an interim basis. Director Lee Woo-hyeon had no intention, and the position was essentially vacant.

The G7 Project was planned as five major projects, ten junior projects, 57 detailed projects, and 72 total projects in research planning, and was implemented as is in the first year. In managing such a massive research project, a high level of expertise was required, and the work system also had to be efficient for research management. When the G7 Project was launched in December 199, the Ministry of Construction and Transportation and the Ministry of Trade, Industry, and Energy were jointly in charge of the project, and the Ministry of Science and Technology was the cooperating ministry. The overall lead organization for the project was the Construction Corporation, and the Korea Institute of Industrial Technology was the cooperating lead organization. In addition, the lead organization for the major project vehicle system was the Korea Institute of Industrial Technology, and the Construction Corporation was the cooperating organization. In addition, the steering committee, which deliberates important matters related to major projects, was not only operated for each of the five major projects but also operated independently of the general steering committee of the general project, making it unable to exercise its function as a general management organization properly. Project selection, budget distribution, and progress often needed more creaks. The conflicting relationship between the Ministry of Construction and Transportation, the Ministry of Trade, Industry and Energy, the Construction Corporation, and the Korea Institute of Industrial Technology also resulted in many conflicts and antagonisms between each research institution conducting research and between researchers.

In particular, the Korea Institute of Industrial Technology raised the issue that the Construction Corporation, the overall management organization, needed to gain experience in project management and that its work system needed to be more suitable for research management. The Korea Institute of Industrial Technology insisted it would become the overall organization or at least a joint management organization. As a result, the promotion of the G7 Project could have been smoother. The Korea Institute of Industrial Technology's claim was accurate, and the Ministry of Construction and Transportation could not deny it. Construction Corporation was an organization that managed railway construction, not a research organization. Because the research organization was attached to such a construction management organization, an appropriate organization was needed to oversee a large-scale national R&D project.

Meanwhile, the Korea Railroad Research Institute, launched in March 1996 as a government-funded research institute, was working to build a research base with the appointment of Dr. Woo-hee Ahn as the first director. Director Woo-hee Ahn has served three consecutive terms at the Korea Electrotechnology Research Institute. He actively supported the implementation of the Ministry of Science and Technology's national project related to high-speed trains, and he has also actively supported maglev train Technology Development. On July 31, 1996, the Korea Railroad Research Institute was designated as a high-speed railway transfer technology-sharing organization by the Ministry of Construction and Transportation. Moreover, the Korea Railroad Research Institute was in charge of the electricity and signal system development project and the track structure development project among the five major projects of the G7 Project.

In this situation, the Ministry of Construction and Transportation promoted the improvement of the research system through the resolution of the Ministers' Meeting of the relevant ministries and the Advanced Technology Development Council, which started in August 1997(4). After completing all consultations, the Ministry of Construction and Transportation revised the “High-speed Train Technology Development Project Operation Guidelines” established for the G7 Project on October 2, 1997, as shown in Table 6, and immediately began implementation.

| Table 3-6 | Improvement of research system of high-speed rail technology development project

Category	Before improvement	After improvement	Remarks
General ministry	Ministry of Construction and Transportation/ Ministry of Trade and Industry	Ministry of Construction and Transportation	
Cooperating ministry	Ministry of Science and Technology	Ministry of Trade and Industry/ Ministry of Science and Technology	
General hosting organization	Korea High-speed Rail Construction Corporation	Korea Railroad Research Institute	
Vehicle system project hosting	Korea Institute of Industrial Technology	Korea Institute of Industrial Technology*	
Operating committee	Operation by each host organization	Abolition of each management committee and absorption of functions into the general management committee	The host organization operates an expert committee

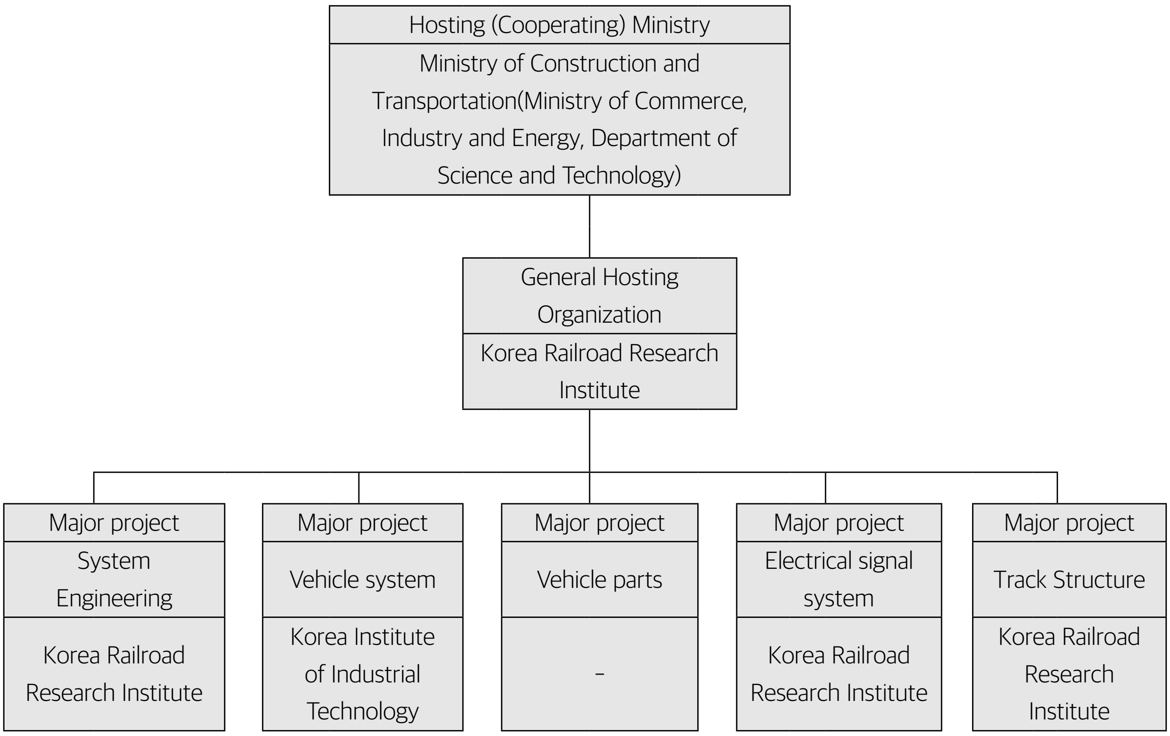
Note *Projects with many interfaces with system engineering technology are transferred to system engineering major projects.

As for the vehicle system major project that the Korea Institute of Industrial Technology was carrying out as the hosting organization, tasks related to system engineering among affiliated

(4) It is believed that these improvements in the Ministry of Construction and Transportation's G7 project promotion system were made with the support of Kim In-ho, Senior Secretary to the Blue House for Economic Affairs. This is the result of a comprehensive review of various circumstances and the author's surrounding remarks made by the Director of the Korea Railroad Research Institute. Kim In-ho, Senior Secretary for Economic Affairs, was appointed as the 19th Commissioner of the Korea Railroad Administration to resolve the debt problem of the Korea Railroad Administration after the Kim Young-sam government canceled the privatization of the National Railroad Administration. He had been working there for about a year and a half, so he had an affection for the railroad.

research projects were switched to the system engineering major project that KRRI was the hosting organization, and the major project operating committee was abolished. The overall hosting organization's control over significant project hosting organizations was strengthened. As a result, KRRI became the overall lead organization for the G7 Project. The issue of the research system was no longer controversial. The implementation system after the improvement of the project implementation system in 1997 is shown in Figure 2.

In 1998, when the 2nd phase of the G7 Project, which started in 1992, ended, there was an interim evaluation of the progress of the entire G7 Project, including the G7 Project that began in 1995 and 1996. The Ministry of Construction and Transportation's high-speed Train G7 project was evaluated over a year after starting research. The Ministry of Science and



| Figure 3-2 | High-speed railway technology development project implementation system (after August 1997)

Source The table is reconstructed by the author.; (source) Korea Railroad Research Institute, (1997.10) Request for Proposal for High-speed Rail Technology Development Project. p.8.

Technology formed the G7 Project Evaluation Committee and evaluated it. The Ministry of Construction and Transportation's High-speed Train G7 project received the lowest rating in this interim evaluation. This was due to disputes over the propulsion system and confusion over development specifications. In research planning, the electric multiple-unit type was adopted as a train type. Still, in early 1997, the Korea Institute of Industrial Technology suddenly ordered a project to review the electric multiple unit type, which needed clarification. Accordingly, Construction Corporation, the overall supervising organization, reviewed the power car type and electric multiple unit type, solidified its policy on the power car type, and put the controversy to rest by notifying the affiliated research project through an official letter. This was analyzed because the disadvantages of driving the power car type and electric multiple unit type on the same route were overlooked. Time and budget were wasted by unnecessarily attempting to review the electric multiple unit types, hindering project execution. Dr. Kim Gi-Hwan took office as project director in early 1998 and normalized the technology development system with a clear development objective. Still, he could not make up for the sluggishness caused by the confusion and confusion.

(3) Efficient Promotion and Successful Completion of the G7 Project

In response to the subsequent IMF crisis, the Project Group actively promoted slimming the project system for efficient implementation of the G7 Project from the third year (starting in November 1998). In other words, the G7 Project initially consisted of 5 major projects and 72 research projects, but it was reduced to 37 projects in 2 areas. In this process, some projects were integrated into others, and some projects (mainly research management projects) were absorbed. This integration and absorption required many procedures over a long period, including many meetings, persuasion, and approval from the government, and there was time to persevere according to the procedures and only then was it possible to change the track with the changed project system. These efforts served as an opportunity to refine further and enhance the project's content. As the project's content became more elaborate and substantial, a rough outline and potential were formed, and the project was successfully carried out without major mistakes or trial and error while it was in progress until 2002.

Afterward, the Project Group worked hard to escape the humiliation of being at the bottom, and the vehicle manufacturer, Korea Railway Vehicle (Inc.) (KOROS)[5], also did its best. By the end of 2002, that is, by the end of the G7 Project’s 2nd phase, we were able to properly carry out the research objectives and research contents set at the beginning of R&D. In March 2002, the first prototype power vehicle was shipped from the Rotem Changwon factory. Afterward, by June, all prototypes' power cars and passenger cars were shipped and assembled into organized trains. Accordingly, KRRI President Song Dal-ho, who took office in January 2002, named the prototype HSR-350x. Here, HSR stands for high-speed railway, 350 stands for a maximum operating speed of 350 km/h, and x stands for experimental cars (eXperimental). The prototype HSR-350x successfully completed factory testing and 60 km/h low-speed commissioning tests at the Rotem Changwon factory. With this, the G7 Project was successfully completed.

(5) In terms of big deals for large corporations due to the 1997 foreign exchange crisis, on July 1, 1999, Korea Railroad Co., Ltd. was established through the integration of the railroad car business divisions of Daewoo Heavy Industries, Hanjin Heavy Industries, and Hyundai Precision Industries. Afterwards, Daewoo Heavy Industries sold its stake in Daewoo Group to Hyundai Motor Co., Ltd. in the aftermath of Daewoo Group's dissolution, then it was relaunched on December 28, 2001, changing its name to Rotem Co., Ltd. Afterwards, Hanjin Heavy Industries sold its shares in 2006 and changed its name to Hyundai Rotem Co., Ltd. on November 15, 2007, and it was listed on the stock market in 2013, and Hyundai Motor Co., Ltd. is currently its largest shareholder with a 43.36% stake.

A final comprehensive evaluation of all 18 G7 Projects ended in August 2003. Unfortunately, the 『High-speed Train Design Technology Development』 project took second place in the final comprehensive evaluation. Considering that it ranked last in the 1998 interim evaluation, it can be said that 『High-speed Train Technology Development』 Project's 2^{nd} phase resulted from the Project Group's efforts to develop HSR-350x.

Disappointing 2^{nd} Place Evaluation for High-speed Train Technology Development Project - Memoirs of Former KRRI Director, Dr. Song Dal-ho
At the end of 2004, a few days after the HSR-350x successfully completed the commissioning test at a speed of 352.4 km/h, I met with Director Son Wook (Samsung Advanced Institute of Technology at the time), who was the chairman of the G7 Project Comprehensive Evaluation Committee. I was acquainted with Director Son Wook. Director Son Wook first congratulated the successful commissioning test at over 350 km/h, saying that in the G7 Project comprehensive evaluation, the High-speed Train G7 project took second place. He wanted to give it first place, but at the time of evaluation (August 2003), it was only driven at a speed of 300 km/h and had not yet reached a speed of 350 km/h, so it was difficult to give it first place. This meant that first place could not be given to a development product whose final performance had not been confirmed. However, he did not spare praise, saying that it was excellent work that accurately demonstrated the role of a government-funded research institute and that KRRI, as the overall management organization, demonstrated leadership in the research project and successfully completed it. He said that the actual contribution of the G7 Project was not significant in the development of the flat panel display that took first place at the time, and even if it were not the G7 Project, it would have been developed by a large home appliances company. In mid-January 1995, at the main auditorium of the Korea Federation of Science and Technology Societies (KFTA), a Science and Technology New Year's Service was held with President Roh Moo-hyun attending. There, a PPT presentation was held on the previous year's research results, and the successful commissioning test of HSR-350x was introduced following the flat panel display. Later, President Roh also expressed interest.

(4) 『High-speed Railway Technology Development』 Project

Now, the final commercialization stage remains, which requires a commissioning test to achieve the prototype's performance objective of 350 km/h speed, secure stability and reliability aimed at commercialization, and establish a high-speed railway system safety and performance standard system. The problem was that the G7 project was scheduled to end in November 2002, but it was the attitude of KRRI Project Group and Rotem. The KRRI Project Group was unsure whether the Ministry of Construction and Transportation would provide additional large-scale research funding. On the one hand, despite the large-scale additional support, we felt a psychological burden over the possibility of commercialization failure, so we hesitated to pursue additional projects. There were doubts about how much more Rotem should invest in commercialization and whether the Korea

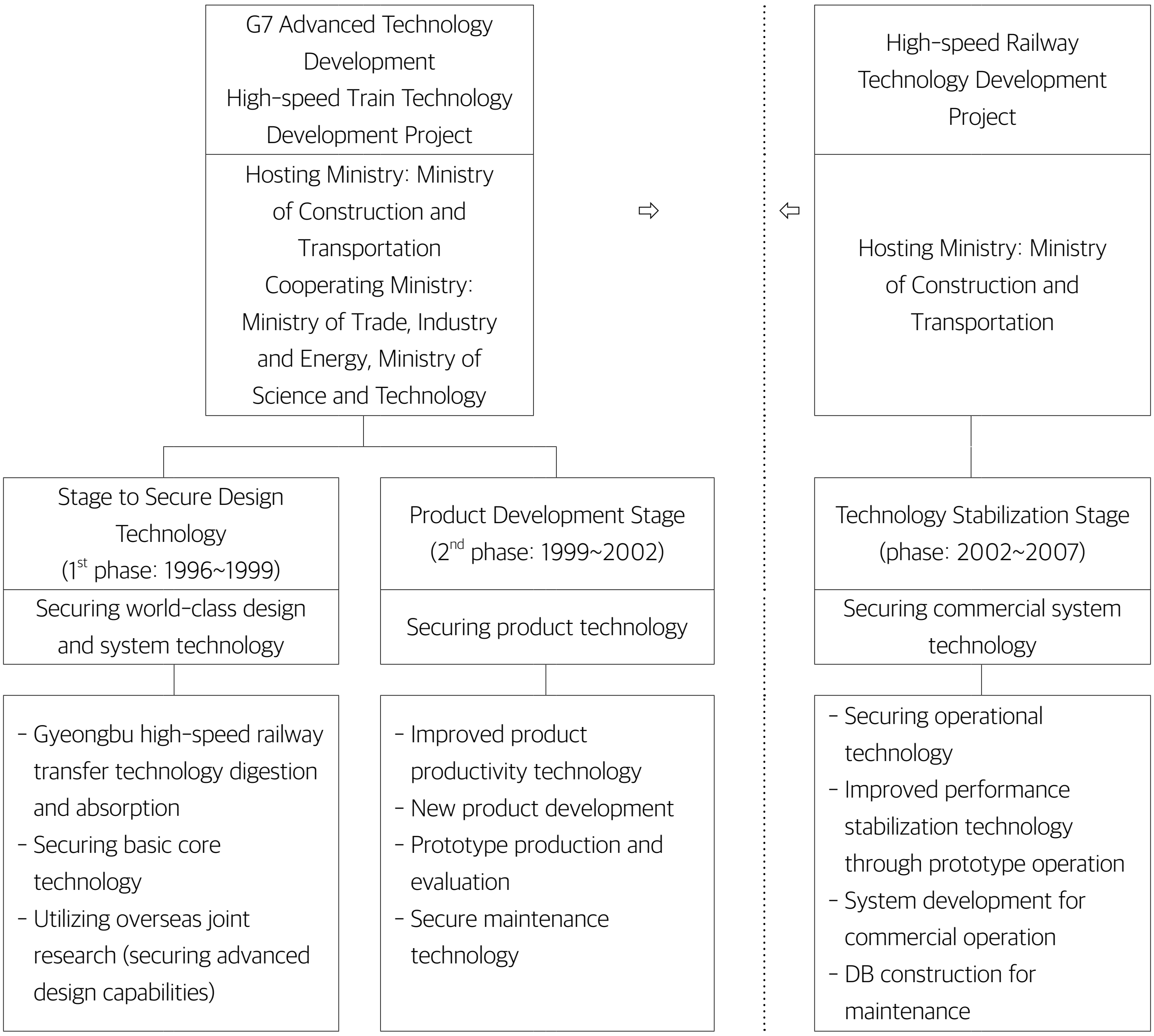
Railroad Corporation would purchase the high-speed train being developed. This is because the Korea Railroad Corporation was skeptical about the G7 Project and was, therefore, not participating in the G7 Project.

Director Song Dal-ho encouraged Project Team Leader Kim Ki-hwan and the Project Team and insisted that the Ministry of Construction and Transportation would provide support and that public enterprises could not easily ignore the train developed with government support. Director Song Dal-ho recalled the Ministry of Construction and Transportation's promise in 1995 when it was conducting competitive research planning for the G7 Project that the Ministry of Construction and Transportation would support commissioning tests outside the G7 Project period. Coincidentally, Park Seong-pyo, manager of the Ministry of Construction and Transportation High-speed Railway in 1995, was promoted to the position of transportation policy manager in 2002. Director Park Seong-pyo agreed without hesitation. Rotem's president, Jeong Hak-jin, was also persuaded by the same logic. In particular, he emphasized that the domestic and global electric vehicle market is a red ocean, that the high-speed train era will arrive, and that a blue sea should be prepared when the government helps. Jeong Hak-jin, president of Rotem, quickly agreed.

Accordingly, the project team developed the 『High-speed Railway Technology Development Project』 and continued the commissioning test of the HSR-350x with approval and budget support from the Ministry of Construction and Transportation. Figure 3 illustrates this relationship.

The HSR-350x, which had completed a low-speed test run at Rotem's Changwon factory at a speed of 60 km/h, was towed by a diesel-electric locomotive (at that time, the Gyeongbu New Line was before its opening, and the existing Gyeongbu Line was before it was electrified), and brought to the Osong depot. The test started at 60 km/h on the main test line near the Osong base. It increased the speed by 30 km/h to verify whether there were any safety issues and whether the performance of each system as originally planned was demonstrated.

For these test runs, sensors were installed in about 400 key devices or major parts of the HSR-350x. We independently developed a computer measurement system to comprehensively collect and analyze the train's performance while running on a central computer and used this to evaluate train performance. In addition, various performance analysis programs necessary for the high-speed train development stage, such as a railway system performance analysis program, track dynamic performance analysis program, and vehicle aerodynamic characteristics analysis program were developed and utilized.



| Figure 3-3 | Korean high-speed train development process

From December 2002, commissioning tests were conducted under the 『High-speed Railway Technology Development』 Project, a commissioning test program exclusively supported by the Ministry of Construction and Transportation. In order to perform commissioning tests smoothly, the "Korea-type High-speed Train Commissioning Team" was operated. The commissioning team also included the KRRI Project Group, vehicle manufacturer Rotem, and the Ministry of Construction and Transportation. The Ministry of Construction and Transportation provided budget support and directly participated in the commissioning team. Korea Railroad Corporation and Construction Corporation, which did not participate in the G7 Project, also participated.

In high-speed driving commissioning tests over 300 km/h, the speed was very carefully increased by 10 km/h. The stability of HSR-350x was secured while continuously improving performance through commissioning tests.

Finally, at 1:12 am on December 16, 2004, it reached 352.4 km/h near Cheonan Unju Tunnel. As a result, it succeeded in driving 350 km/h, which was set as the objective of the G7 Project. This was the fourth record in the world, following Japan, France, and Germany.

The commissioning team continuously conducted commissioning tests. By October 2007, the commissioning test record of 209,406km was achieved, laying the foundation for commercialization. Accordingly, the commissioning test for HSR-350x was completed.

However, the commissioning test took longer than expected, and this was because the commissioning test was performed on the completed Gyeongbu New Line, and track allocation needed to be smoother due to competition with the KTX train in commercial operation.

(5) Commercialization and Technological Significance of KTX-Sancheon

Gyeongbu high-speed railway vehicle KTX, Korea's first high-speed train, is a train based on France's TGV, with 34 of the 46 trains produced domestically and 44 trains assembled domestically. However, it was a train designed by France. The development of the Korea-type high-speed train KTX-Sancheon is a historical event in the Korean railway, which has an important meaning in that Korea's railway technology is on par with advanced railway countries.

Table 7 shows the relationship between the Korea-type high-speed train KTX-Sancheon and prototype HSR-350x.

A prototype of the Korea-type high-speed train, HSR-350x, took a total of 13 years of research since research planning began in August 1995. There were many changes and difficulties during this long research process. There also needed to be more clarity in the initial project system and specifications, changes in the project system, changes in research institutes, technological problems in the research process, and bankruptcy of companies participating in the project. After overcoming all these difficulties, we independently developed Korea's first state-of-the-art high-speed train with a maximum driving speed of 350 km/h. For reference, the localization rate of HSR-350x is 87% in terms of price and 92% in terms of number of parts. The parts that were not produced domestically were due to price competitiveness. In other words, parts such as bearings, springs, special screws, etc., that could be freely purchased at a lower price from international markets than from domestic production were excluded from domestic production.

In mid-2005, when the commissioning test of the HSR-350x was in full swing, Korea Railroad Corporation submitted international competitive bidding for the KTX follow-up quantity (maximum driving speed 300 km/h). Korea Railroad Corporation did not provide any benefits to the HSR-350x-based train, even though it was a vehicle developed by a national research project. It was very disappointing, and Rotem and everyone else were very anxious. There were many rumors that Alstom[(6)] would propose an AGV-based train. In the bid evaluation conducted at the end of November, Rotem's HSR-350x-based KTX-Sancheon (the name given later) and Alstom's AGV-based

(6) In June 1998, the name was changed from GEC-Al:sthom to Alstom.

train competed. In the proposal's content, there were clear signs that Alstom's AGV was still under development, and naturally, Rotem's KTX-Sancheon became the preferred bidder. After tedious technology negotiations, a contract for 10 KTX-Sancheon trains was signed on June 30, 2006.

| Table 3-7 | Overview of Korean high-speed train development project

<table>
<tr><th>Purpose</th><th colspan="3">Development of Korean high-speed train</th></tr>
<tr><td>Project name</td><td colspan="2">High-speed electric railway technology development project</td><td>High-speed railway technology development project</td></tr>
<tr><td>Business nature</td><td colspan="2">Leading technology development project
(G7 project)</td><td>The G7 business</td></tr>
<tr><td>Department of Support</td><td colspan="2">Ministry of Construction and Transportation (supervising), Ministry of Trade, Industry, and Industry + Department of Engineering (cooperation)</td><td>Ministry of Construction and Transportation</td></tr>
<tr><td>Project goal</td><td colspan="2">Korean high-speed electric railway system
(Maximum driving speed 350 km/h)</td><td>Stabilizing Korean high-speed railway technology, securing reliability, establishing performance standards and safety systems</td></tr>
<tr><td>Project term</td><td colspan="2">6 years (1996.12 ~ 2002.10)</td><td>5 years (2002.12 ~ 2007.10)</td></tr>
<tr><td>Project phase</td><td>1st phase: Acquiring Design Technology
1996.12 ~ 1999.10</td><td>2nd phase: Product development phase
1999.11 ~ 2002.10</td><td>3rd phase: Technology Stabilization Phase
2002.11 ~ 2007.10</td></tr>
<tr><td>Phase goal</td><td>Securing world-class design and system technology</td><td>Securing product technology</td><td>Securing commercial system technology</td></tr>
<tr><td>What to do</td><td>- KTX previous technology digestion absorption
- Securing basic core technology
- Utilization of overseas joint research (securing advanced design capabilities)</td><td>- Product production technology improvement
- New product development
- Making and evaluating the car
- Securing maintenance technology</td><td>- Securing operational skills
- Improved train performance stabilization technology
- Commercial driving system development
- DB construction for maintenance</td></tr>
<tr><td>Project expenses</td><td colspan="2">210 billion ₩
(Government 105.1 billion won,
Private 104.9 billion won)</td><td>45.7 billion ₩
(Government 35.3 billion won,
Private 10.4 billion won)</td></tr>
<tr><td>Participating institutions</td><td colspan="2">129 institutions ((82 companies,
18 institutes, 29 universities)
(KORAIL, Construction Corporation, etc.
not participated)</td><td>28 institutions (including KRRI, Rotem, enterprises, etc.) (Participation: the Ministry of Construction and Transportation, KORAIL, and the Construction and Industrial complex)</td></tr>
<tr><td>Number of participants</td><td colspan="2">4,934
(Corporate 3,089, Institute 1,254,
University 569, other 21)</td><td>-</td></tr>
<tr><td>Project results</td><td colspan="2">HSR-350x 7-car, 1 set
(Test train, P+5T+P)</td><td>KTX-Sancheon
(Commercial trains, P+8T+P)</td></tr>
</table>

| Figure 3-4 | HSR-350x, KTX, and KTX-Sancheon (from left)

Source High-Speed Rail Technology Development Project Group

Afterwards, on March 2, 2010, KTX-Sancheon entered commercial operation. Even though the first train developed domestically was opened, there were no events. Everyone has forgotten the excitement about the first domestic train developed. This is a regrettable part.

Since then, more than 70 KTX-Sancheon units have been delivered to the Honam Line, Suseo Line, and Wongang Line. This is a sales volume of approximately 2.3 trillion won. Considering that the research cost invested in the development of KTX-Sancheon was approximately 260 billion won, it is clear that sufficient economic effects were achieved. In addition, the extent to which it has contributed to the increase in national competitiveness and the development of other industries is innumerable. In addition, the development of the Korea-type high-speed train is a train station event that puts Korea's railway technology level on par with advanced railway countries.

Domestic railway history shows clear technological differences before and after the introduction of high-speed railways. These changes are largely due to our own technology development rather than the effect of introducing vehicles. During the technology development process, many human resources were trained, social interest in railways increased, related industries also developed, and the effect of expanding the railway base was achieved. There was also another effect of promoting our railway technology globally. Now, the country's status has been raised to an exporter rather than an importer of high-speed railways. Besides, as the large-scale R&D Project was successfully completed, many railway-related projects were created in the future, and a model that could be used as a reference in many research projects was created.

(6) Leading Role in Technology Development

Many organizations participated in R&D. KRRI formed the High-speed Train Technology Development Project Group, and the Project Group oversaw the entire project, determined the technology specifications of the system, and conducted research to verify the performance of the system and performance evaluation. In addition, he led technology development by supervising the electric signal and line construction fields. Korea Institute of Industrial Technology took charge of the vehicle field and managed vehicle and parts development.

The research institutes for many parts and device development projects were selected mainly from organizations (multiple companies) that received technology transfer from France through the Gyeongbu high-speed railway project. Almost all domestic railway-related institutions participated, including government-funded research institutes (KIMM, KERI, etc.) related to railway technology and universities that research related fields. A total of 129 institutions participated in the G7 Project from 1996 to 2001, and each year, approximately 937 researchers shared their respective research functions.

There were many people's efforts, from the Project Leader who led the entire project, to the researchers who participated in each research project and devoted themselves to research day and night, to the personnel who assisted with administrative affairs to lead this huge project. Construction Corporation wanted to appoint Dr. Lee Hae as the project leader; however, in opposition to the Korea Institute of Industrial Technology, Lee Woo-hyeon, head of the vehicle division, took charge. However, Director Lee Woo-hyeon was a non-expert in R&D, so in reality, the position was vacant. Dr. Hong Jin-wan took over as project leader as the G7 Project's lead agency was transferred to KRRI. Dr. Hong served as Project Leader for about two years and then left KRRI due to personal reasons. Afterwards, Dr. Kim Ki-hwan served as Project Leader. Dr. Kim worked for eight years, including three years for the G7 Project’s 2nd phase, which started in late 1998, and 5 years for the high-speed railway Technology Development Project, which continued until 2007. The G7 Project was successfully completed, and as the G7 Project was coming to an end, the high-speed railway Technology Development Project, supported by the Ministry of Construction and Transportation, was created amicably with then-director Song Dal-ho. By 2007, the commissioning test was completed, contributing greatly to developing the G7 train (HSR-350x). KTX-Sancheon was born based on HSR-350x

In addition, Dr. Park Chun-su, who assisted the Project Leader and participated in determining system specifications for the final completion of the project, Dr. Kim Seok-won, who overcame difficulties as the next test director in the commissioning test, and Lee Byeong-seok, director of Hyundai Rotem, who participated in vehicle development and carried out final commercialization, can be said to be major researchers. In addition to former directors Ahn Woo-hee, Lee Heon-seok, Song Dal-ho, and Chae Nam-hee, who supported us both financially and spiritually, many researchers from industry, academia, and research institutes fulfilled their responsibilities in their respective fields. Hence, the initial difficulties could be overcome, and final commercialization was achieved.

In particular, Dr. Song Dal-ho's contribution was absolute. First, he raised the issue of technology transfers while introducing the Gyeongbu High-speed Train and represented domestic experts in selecting the model. When TGV was selected in model selection, he predicted that the design technology transfer would be difficult. He persuaded the government to undertake High-speed Train Technology Development. In this process, he decided on the basic specifications of the new Korea-type high-speed Train. He served as the general manager of the Ministry of Science and Technology's High-speed Train Design Technology Development Project. Research planning for the G7 Project was carried out on behalf of the Construction Corporation (Ministry of Construction and Transportation). The Ministry of Construction and Transportation played a decisive role in becoming the lead ministry for the High-speed Train Technology Development Project. In the G7 Project, he was responsible for the mid-project-based technology project belonging to the system engineering major project. The basic technology project included projects researching basic technologies such as structural analysis, including fatigue analysis, dynamic analysis, aerodynamic analysis, noise and vibration analysis, and collision analysis. Dr. Song Dal-ho was appointed the director of the Korea Railroad Research Institute in mid-January 2002. He took a special interest in and supported the smooth completion of the G7 Project, establishing the 'High-speed Railway Technology Development Project' for commissioning tests and the successful performance of driving tests. Deputy Prime Minister Oh Myung called Dr. Song Dal-ho the 'father of Korea's high-speed train' and honored his contributions at the 21C railway forum in July 2005(7).

(7) In the author's opinion, Deputy Prime Minister Oh said these words from the memory of when he was the Minister of Construction and Transportation in May 2005, when he instructed Park Seong-pyo, then head of the High-speed Rail Division, and Lee Woo-hyun, head of the Korea Construction Corporation's Vehicle Division, not to let the Ministry of Trade, Industry and Energy take charge of the 「High-speed Rail Technology Development」 project.

Section 4 Decentralized High-speed Train Development Project (HEMU Development Project)

(1) Technology Development Details

We put a lot of time and effort into developing the ‘power car type’ Korea-type high-speed train (HSR-350x) and even succeeded in commercialization (KTX-Sancheon). However, at the time, advanced countries in high-speed railways were completing the development of ‘electric multiple unit type’ high-speed trains to increase speed and transport capacity. They were making every effort to dominate overseas markets. Japan has been an electric multiple-unit type since the beginning of development. JR East Japan launched the Shinkansen High-speed conversion project in April 2002 and developed a prototype test train called ‘FASTECH ’360’ in June 2005. As a result, it was announced that high-speed train technology for commercial operation at a speed of 360 km/h has been secured. In addition, France and Germany were developing electric multiple unit type AGV and ICE-3 trains based on the technology and experience of existing power car type TGV and ICE trains to maintain a competitive advantage in the global high-speed railroad market.

Therefore, KRRI decided to develop an electric multiple-unit high-speed train based on power car-type high-speed train technology to cope with the changing international environment and strengthen overseas market competitiveness with developed countries. In November 2005, we began researching and planning to develop next-generation high-speed railway technology. Planning was completed in December 2006 after seven sessions of gathering opinions from related organizations and experts, three planning committees (chaired by Professor Song Dal-ho of Woosong University), and subcommittee meetings. In July 2007, the next-generation high-speed railway technology development project was launched, an electric multiple unit type high-speed train development project.

In this project, under the supervision of the Ministry of Land, Transport and Maritime Affairs, around 50 industries, academia, and research institutes participated, including KRRI, Hyundai Rotem, LG Industrial Systems, Eugene Engineering & Construction, Seoul University, and Woosong University. The 1st phase (2007.7~2012.9) project was regarding the Next Generation High-speed Railway Technology Development, and the 2nd phase (November 2012~December 2015) project was regarding the 430 km/h-grade High-speed Train (HEMU-430X) commercialization Technology Development.

(2) HEMU-400x

The project aimed to develop an electric multiple unit type, next-generation high-speed train with a maximum speed of 400 km/h or more, surpassing the maximum speed of KTX and KTX-Sancheon using pure domestic technology. Unlike the power car type KTX or KTX-Sancheon, which has power installed only at the front and rear of the train, acceleration and deceleration performance could be greatly improved by adopting an electric multiple unit type that distributes power to multiple vehicles in the train.

While it takes 5 minutes and 16 seconds for KTX-Sancheon to accelerate from a standstill to 300 km/h, Next Generation High-speed Train “HEMU” can reach it in 3 minutes and 53 seconds. Braking performance also improved from 23 MJ of KTX-Sancheon to 43 MJ. In addition, the electric multiple unit type design made it possible to board passengers in both the front and rear vehicles, increasing the number of passengers per train by about 40% from 363 to 533 in the KTX-Sancheon.

The distributed arrangement of the propulsion system reduces the maximum axle load of the existing power car type high-speed train by about 3 tons compared to 17 tons, reducing infrastructure maintenance costs such as track roadbeds. The weight of the vehicle body was reduced by 5% by the optimal design of aluminum extrusions, and the sound insulation performance was improved by 3dB compared to the existing model.

The on-board signal device is an integrated on-board signal system that can be used in all signal systems of ATP, ATC, and ATS used in existing domestic lines and high-speed railway lines and was developed with pure Korean technology. In addition, a maximum speed of 430 km/h independent bogie, a high-performance braking system, and a low-noise pantograph were developed for the application of an electric multiple unit type system. Passenger convenience facilities have been developed using cutting-edge IT technology, including a passenger seat LCD information device, crew remote call service, automatic monitoring of the train cabin construction period using intelligent smart sensors, and restroom emergency detection notification.

The train's name to be developed was ‘HEMU (High-speed Electric Multiple Unit)-400X’. HEMU means testing electric multiple unit types and high-speed trains, and 400 means testing at 400 km/h. In Korean, it means ‘sea fog,’ and in Chinese characters, it means ‘auspicious sea fog (海霧)’ and ‘running fast (駭騖).’ X (eXperimental) was added to the end to mean the test train. The number following the train name generally indicates maximum driving speed. In fact, there is no technical term for testing maximum speed. I don’t understand why it was named this way.

(3) HEMU-430x

The original objective of the next-generation high-speed railway Technology Development Project was to develop an electric multiple unit type, high-speed train with a maximum test speed of 400 km/h (commercial speed 350 km/h) over a period of 6 years; however, In May 2010, there were some changes to the project period and project objectives, such as shortening the project period by one year to 5 years and increasing the maximum driving speed to 370 km/h. Afterwards, in 2011, the highest test speed objective was raised to 430 km/h. Therefore, the name of the developing train became HEMU-430X.

(4) Technology Development Course

The next-generation high-speed train HEMU, which began development with our technology, analyzed the technology specifications of other countries and developed operational requirements and technology specifications that satisfy domestic operating conditions. Two research institutes developed the vehicle's exterior and interior design, and Han Ye-jong's work was selected through expert evaluation in January 2009.

On February 1, 2012, the next-generation high-speed train with a speed of 430 km/h was finally built to compete in the global high-speed railroad market. For mainline commissioning tests such as performance tests and speed improvement for development vehicles, a TF was formed for the『next-generation high-speed train commissioning team』in which KRRI, KORAIL, Facilities Corporation, Hyundai Rotem, etc. participate. The KORAIL Busan High-speed Railway vehicle maintenance group was chosen to be the commissioning test base, and the office was opened in May 2012.

Full-scale commissioning tests on the high-speed railway line main line began on June 28, 2012, at the Gyeongbu high-speed railway line Busan⊠Ulsan section with an operation speed of 150 km/h. Afterward, performance verification and stabilization began through night test runs on the Gyeongbu high-speed railway line between Busan and Gomo. HEMU-430X departed Busan Station at 11:30 on September 8, 2012, and gradually increased its speed, exceeding 300 km/h around midnight on the 9th and reaching 354.7 km/h at 03:03. It took 41 minutes from Busan to Dongdaegu. This new record surpassed the Korea High-speed Railway's maximum speed of 352.4 km/h set on December 16, 2004. It was a breakthrough after seven years and nine months.

Increased speed testing continued to reach the objective speed. In the Gyeongbu high-speed railway line Busan~Gomo 120km section, the operation speed was increased stepwise at night when KTX was not running and was carried out twice a week. After continuing 23 tests, it succeeded in the 401.4 km/h test at 3:12 am on December 27, 2012, exceeding 400 km/h. Then, on March 28, 2013, HEMU-430X completed the maximum speed increase test, recording a maximum speed of 421 km/h. This was achieved after ten months of shipping and commissioning on May 16, 2012, and 138 speed-up tests over 55 rounds.

As a result, Korea became the country with the world's fourth fastest high-speed railway record, following France, Japan, and China, and opened a new era for the Korean high-speed railway. As a result, HEMU has the ability to travel across the country in 1 hour and 30 minutes. This was an achievement achieved with its own technology in 8 years since it entered the 300 km/h range in 2004 with the introduction of French technology.

Compared to foreign countries where tests are mainly conducted on long-distance straight sections, Korea has very unfavorable conditions for increasing speed. Of the 68.5km increased speed test section from Ulsan Station to Gomo Station near Dongdaegu, only the 39.8km uphill section (58%) is straight. In addition, 49.2% of the total test section is mountainous, and the tunnel section is 33.85km long. Air resistance increases by about 30% in the tunnel section compared to open terrain. If the speed increase test had been conducted under the same track conditions as in France, it was predicted that the 421.4 km/h achieved by the HEMU-430X could be increased to 466 km/h. Additionally, simulation results assuming open terrain without a tunnel in the test section showed that a maximum speed of 444 km/h was possible.

| Figure 3-5 | HEMU-430X commemorative photo of achieving maximum speed

Source Korea Railroad Research Institute

(5) Meaning of Technology Development in Light of Today

The Next Generation High-speed Train HEMU-430X has been tested for commissioning a total of 229 times as of December 2015, with a driving distance of 121,123km (as of December 27, 2015), which is more than three times the circumference of the Earth. During the commissioning test, stability tests were performed on the vehicle's main performance items, such as driving stability, current collection quality, propulsion performance, and braking performance. As a result, it was confirmed that all international standards and domestic Railway Safety Act standards were met, and the objective for stabilization was achieved.

| Figure 3-6 | HEMU-430X appearance photo

Source Korea Railroad Research Institute

In addition, HEMU-430X, based on verification results through stability test, promoted national R&D excellence and obtained NET New Technology certification for electric multiple unit type propulsion technology for high-speed trains (Year 2013) and ATP/ATC/ATS onboard signal integrated processing technology (Year 2015), and won the 2016 Korea Technology Grand Prize (Year 2016).

To respond to the speed requested by the operator, the models of HEMU, an electric multiple unit type, the high-speed train that has been developed were divided into four-speed bands: 250 km/h, 300 km/h, 350 km/h, and 370 km/h, and specifications for commercial models were prepared.

Through the conclusion of a purchase contract with KORAIL in June 2016, among the commercial models, the HEMU-250 (250 km/h speed model) has been commercialized for 30 high-speed trains to be deployed on the Gyeongjeon Line (Bujeon~Sunjeon). Here, 250 means a maximum driving speed of 250 km/h. This is why it was pointed out that the naming of HEMU-430X was strange. 430 is the highest test speed.

Afterward, an additional 16 vehicles were proposed as the HEMU-300 model to operate the existing high-speed railway line in Korea, and a contract was signed (December 2016). A total of 84 units of Seohae Line, Jungang Line, and Jungbu Naeryuk Line were additionally contracted for the HEMU-250 model (December 2016). Through R&D on the next generation high-speed train, in addition to securing technology for electric multiple unit type and high-speed train, the commercialization of an electric multiple unit type, high-speed train using the developed technology was successfully completed.

The developed prototype train HEMU-430X has fulfilled its original duties. Still, it continues to serve as a test vehicle for testing various developed products related to high-speed trains on the high-speed railway line.

South Korea has entered the ranks of advanced countries in the high-speed railway sector. Domestic engineers independently developed a power car type, electric multiple unit type, and high-speed train model, and both models were successfully commercialized. Considering that the high-speed railway KTX was opened in 2004 by introducing foreign technology, it is a remarkable development.

The development of the Korean high-speed railway system has left a very meaningful milestone in the history of our railway technology and has greatly contributed to the development of railways and other industries.

Now, we must make a national effort to ensure that the high-speed train we have developed can advance to Asia and the rest of the world. Technology development must be carried out continuously, and technology development in preparation for future railways must continue.

(6) Major Role Players of Technology Development

The Next Generation High-speed Railway Technology Development Project was led by organizations and personnel participating in the Korea-type High-speed Train Technology Development Project. Many people from various fields, including industry, academia, and research institutes, participated, including the project leader who oversaw the entire project, participating researchers, advisors, and administrative support personnel. The project leader was Dr. Kim Ki-hwan during the first stage of the Technology Development Project following the Korean High-speed

Train, and Dr. Kim Seok-won during the second stage of the commercialization project.

The project's core areas, the field of system engineering for determining system specifications and performance testing was covered by Dr. Park Chun-soo; Professor Song Dal-ho of Woosong University covered the field of basic technology for vehicle performance and operation; the vehicle development field was covered by Hyundai Rotem's Director Lee Byeong-seok and Manager Min Pyeong-oh. In addition, many researchers participated and successfully completed R&D by demonstrating their respective roles and abilities.

04

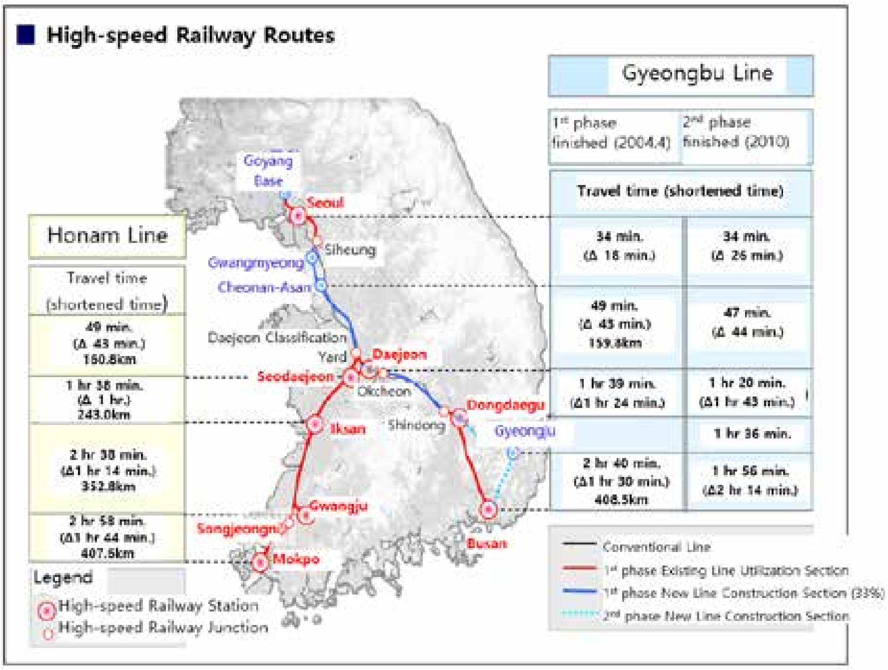
KTX: 20 Years of History

High-speed Rail Operation

04 High-speed Rail Operation

Section 1 Situation at the beginning of the Opening of Gyeongbu High-speed Railway's 1st Phase in April 2004

April 1, 2004, for general passengers who have reserved tickets through the ticket reservation system starting from the first train at dawn, KTX commercial service began on the Gyeongbu high-speed railway and Honam Line double-track train, thus ushering in the era of High-speed Railway in Korea. The key to high-speed railway competitiveness lies in shortening operating times through faster train speeds. The 2-3 hour living zone was realized in the Gyeongbu and Honam axes, contributing to individual time savings, improved work efficiency, increased convenience, and enhanced national competitiveness. The travel time between Seoul and Daegu was 3 hours and 3 minutes on the Saemaul-ho train, but the high-speed train runs at 1 hour and 39 minutes, reducing it by almost half.



| Figure 4-1 | High-speed Rail 1st phase operation route

Source Kim Cheon-hwan, "Korea high-speed Rail Operation and Plan to Strengthen International Competitiveness," Korean Railway Society 2004 Fall Conference Papers, 2004. p89)

With the operation of high-speed trains, railway transportation capacity has also doubled. As of 2003, the number of long-distance train operations on the Gyeongbu-Honam axis increased from 128 to 171 after the opening of the high-speed railway in 2004, an increase of 34%. The number of seats supplied increased 2.3 times from 47,296 to 107,830. This dramatic improvement in railway transportation capacity has resulted in large-scale benefits such as reduced traffic congestion, logistics costs, and environmental improvements. The airplane switched to an overseas route or a specific domestic route such as Jeju Island, and express buses increased mid- to long-distance and short-distance routes in areas where high-speed railways did not operate, thereby the role distribution of domestic transportation such as railway, bus, and airplane had been efficiently reorganized.

After the opening of the high-speed railway, we experienced an initial period of failure. We entered a period of stability, and KTX has deeply penetrated people's daily lives. The number of passengers using KTX exceeded 1 million just 14 days after opening, and the number of people exceeded 10 million in 142 days, setting a record faster than when the Japanese Shinkansen or French TGV opened.

However, our media, which had very high expectations for the high-speed railway, poured out a lot of criticism immediately after its opening in April 2004, when it was difficult to feel the macroscopic changes brought about by the high-speed railway. Summarizing the problems pointed out, they could be broadly classified into three categories: First, the criticism that since the opening of the high-speed railway, there had been more than 20 successive breakdowns and subsequent delayed operations, so high-speed trains did not guarantee safety as well as high speed; Second, the criticism that the high-speed train, called the 'dream train' was inferior to the Saemaul-ho train in terms of reverse-facing seats, inaudible TV, and tunnel noise, and ticket issuance system, including online reservations, was also confusing, so there was lack of various services; and thirdly, the criticism that the general trains were excessively reduced and service deteriorated, but the burden on the common people was increased due to the fare increase.

Criticism in the early days of the KTX's opening largely stemmed from a problem of perception regarding how high-speed railways were viewed. Regarding the KTX, which provided new value by reducing travel time due to high speed, the price was 30% more expensive than the Saemaul-ho train, but the main criticism was that the interior facilities, such as reverse seats, were inferior to Saemaul-ho. Rather than accepting the change in which high-speed trains take on the main transport role on the Gyeongbu-Honam axis, and regular trains play a complementary role in connecting transport with high-speed railway stops, regular trains such as the Mugunghwa were falsely framed as trains used by ordinary people who had difficulty riding expensive high-speed trains. In particular, regarding the reduction of general mainline trains, Suwon City's voice of dissatisfaction was loud because even though Gyeonggi-do is the transportation center of the southern region, Suwon found it challenging to use the KTX since the KTX station was far away, and people living in the areas where KTX did not stop were also dissatisfied.

According to the guidelines from the Ministry of Construction and Transportation, general railways must be operated from the perspective of public interest, but high-speed railways must be operated from the perspective of profitability, and to this end, the high-speed railway operating organization was also requested to be separated. This contributed to the approach of classifying high-speed railways and general railways by grade. Korean National Railroad was first established in 1998. Afterward, according to the 'integrated train operation plan of high-speed railway and general railway,' which was slightly modified, KNR planned to significantly convert general mainline trains such as Saemaul-ho and Mugunghwa trains to section-connected trains on the Gyeongbu and Honam axes. However, in 2003, when government guidelines were issued to separate the high-speed railway operating organization from the general railway operating organization, the general railway project headquarters of the Korean National Railroad, which had standard business functions in the sales field, recognized high-speed railways with other operating departments as competitors, and focused on reviving the general railway train.

When Acting President Goh Kun faced increasing criticism from the media, he did not give the Korean National Railroad a chance to persuade the press. Instead, he ordered prompt action to alleviate inconvenience to the ordinary people just one week after the opening of the high-speed railway, thereby strengthening the erroneous frame that divides high-speed railways and general railways according to the user classes of the rich and the common people. In accordance with this instruction, the general railway project headquarters of the Korean National Railroad immediately reduced the fares of Saemaul-ho and Mugunghwa-ho by 10%. The section connecting trains on the Gyeongbu and Honam Axes were converted to mid- to long-distance trains as before, so general railway and high-speed railway trains were competing on the same route axis.

Korean National Railroad quickly reduced and stabilized initial failures within two to three weeks after the opening of the high-speed railway, while complaints were alleviated with a policy of offering a 5% discount on fares for seats facing backward and uncomfortable seats adjacent to the entrance door. In particular, regarding the central table seats, which had many complaints because passengers' knees almost touched each other, KNR introduced the 'KTX Companion Seat' system, which bundles four seats together and sells them at a discount (37.5%) at the fare for 2.5 people, thereby it was so popular among travelers traveling with four people that the new term 'KTX Carpool' became popular on the Internet. All dull analog monitors in High-speed vehicle train cabins, which had many complaints about lack of subtitles, were replaced with the latest LED monitors. Hence, the competitiveness of high-speed railways increased by starting real-time news and subtitled broadcasting.

| Figure 4-2 | Seoul Station

Source Korea Railroad Research Institute

Section 2 Organizational Reorganization and Improvement of High-speed Railway Operating System after Korea Railroad Corporation

1. Organizational Reorganization after Korea Railroad Corporation

In January 2005, the Korean National Railroad converted to Korail. Following the railway structural reform that adopted the separation of infrastructure and operations like railways in Europe, the roles and responsibilities of the government, Korea Rail Network Corporation, and Korea Railroad Corporation were clearly separated, so the way the railway operated fundamentally changed from the days of the Korean National Railroad.

At the time of the Korea Railroad Corporation's launch, the headquarters was organized using a traditional functional system to ensure organizational stability during the transition from the Korean National Railroad to construction. The general railway project headquarters changed to the passenger project headquarters with an executive director as the head. The high-speed railway Project headquarters was changed to the High-speed Project Group, headed by a first-class director, clearly demonstrating the status of general railway and high-speed railway within the construction.

As soon as the Korea Railroad Corporation was launched, among the new projects that had been ambitiously developed since 2004 in preparation for the transition to construction, the Sakhalin oil field development project fell into a deep quagmire of suspicions raised by the media and prosecution investigations. Hence, the corporation's first executives experienced the ordeal of all resigning after less than a year. Stability was restored only after the inauguration of the second president. November 2005, in order to break away from the inertia of the government organization, the headquarters organization by the functional system was changed to a project department organization by the market in a practical sense. The general railway and high-speed railway departments, which were in charge of the major passenger market but were competing with each other, were integrated into the passenger project headquarters. The barriers to traditional hierarchy were also broken down in upper-level personnel management.

The passenger project headquarters was organized into eight teams according to the work process to increase the efficiency of the entire main railway, focusing on the high-speed railway. These were the passenger planning team, customer support team, passenger marketing team, passenger transportation team, station operation team, train sales team, distribution management team, sales development team, etc. However, the management accounting of high-speed railways and general railways was differentiated to enable a detailed analysis of the profits and costs of each.

The following year, in mid-2006, the railway business organization was reorganized and transformed from a government office-type organization in the 3rd phase to a corporate-type organization in the 2nd phase. Starting with the reorganization of the regional organization and the relocation of the Seoul regional command center to the rail transport control center in Guro, which was completed in May 2006, each regional headquarters command center was sequentially relocated by December of the same year. The high-speed railway control room installed at Gwangmyeong Station was also relocated and integrated into the process of railway structural reform; rail transportation control was classified as a national responsibility like other transportation methods such as airplanes. Infrastructure maintenance work was entrusted to the Korea Railroad Corporation to promote structural reform. The organizational reorganization was completed only at the end of 2006.

Korea Railroad Corporation established a comprehensive control room at its headquarters to oversee railway control functions to carry out government-entrusted projects. Guro's rail transport control center was appointed as an affiliated organization. Guro's rail transport control center was built around the CTC, where the controller directly handled the train's route through the control console. In addition, to efficiently perform transportation coordination work, a unique function of Korea Railroad Corporation, a ‘comprehensive operation situation room,’ was installed in the same space as the headquarters’ general control room. There were situation teams in charge of transportation coordination and maintenance coordination functions, including the passenger situation team, logistics situation team, and vehicle, facility, and electricity situation team. The ‘Passenger Situation Team,’ which was responsible for the operation management of mainline passenger trains focusing on high-speed trains, was in charge of power vehicle and crew operations and operates a revenue management system and consisted of the MC (Management Center)-KTX, which was in charge of seat management, and the Help Desk, which was in charge of field sales department support, thereby a 3-team, 2-shift work system was organized to manage train operations and business situations on site 24 hours a day.

2. High-speed Railway Operating System Improvement

The KTX fare system at the beginning of its opening was calculated by dividing the wage rate of the existing line and the new high-speed line into the basic wage rate and characteristic wage rate and adding them up. When opening, the KTX fare between Seoul and Busan was set at 45,000 won, which was 122% compared to Saemaul-ho and 63.8% compared to airplanes. The KTX fare between Yongsan and Mokpo was 41,400 won, which was 120% of the Saemaul-ho fare and 61% of the airplane fare. Regular KTX commuting and school passes with a high discount rate of up to 60% were issued, and to attract demand for business trips from employees of large groups, various discount systems were introduced and operated, including contract transportation with a 15% discount rate.

Since 2006, the passenger project headquarters has been divided into high-speed railway and general railway, and we have significantly integrated and revised various sales systems and systems that have been maintained as a dual system, increasing customer convenience and competitiveness of high-speed railway. The railway membership system, which was operated in a complicated manner, was also improved by consolidating it into one Korail membership according to the improvement of the ticket reservation system. However, it is not easy to completely convert the regular mainline trains on the Gyeongbu and Honam Axes, which were revived to appease complaints immediately after the opening of the high-speed railway, back to section-linked trains, so The train operation system was reorganized once or twice a year, gradually increasing the number of high-speed trains. high-speed railway transportation performance remained at only half of the demand forecast. It was an inevitable choice in conditions with high demand for general railway transportation until an appropriate opportunity was provided with the additional introduction of high-speed rolling stock and the opening of the Gyeongbu high-speed railway's 2nd phase project.

Due to the limit of 46 KTX vehicles, it was challenging to increase the number of operations until the KTX-Sancheon was introduced in 2010; however, we operated our reserves to the fullest, increasing from 136 to 142 times on weekdays from 2005 to 2009, and from 160 times in 2005 to 181 times on weekends when demand was high.

When the high-speed railway opened, the ATB2 type of ticket, similar to the airplane boarding pass, was introduced, and a station automation system was installed and operated to count and collect tickets through automatic gates when entering or leaving the platform at the station. However, starting in 2006, counting and collecting votes at stations was omitted entirely, and automatic gates that revealed their limitations were removed. Customers could take the tickets as receipts or discount coupons for delay compensation. We strengthened in-vehicle ticket checking, rather than checking each passenger's ticket individually, and an improvement was made by checking the passenger boarding status using the flight attendant's portable terminal. According to changes in ticket checking, ticket collection, and ticket inspection methods, replacing the expensive ATB2 type with a roll-type paper ticket containing more information reduced costs and improved customer convenience. In addition, we have developed home tickets that allow customers to print their reserved tickets using their own printer directly and SMS tickets that replace paper tickets with mobile phone text messages, so distribution costs were reduced by increasing the use of self-issued tickets.

After becoming a public corporation, the mindset of railway employees changed to a sales mindset. For example, in 2006, we developed a project to rent out Seoul Station employee conference room space to external parties. The railway station served as an early pioneer of today's widespread conference room rental project. KTX Express Project, which uses KTX's idle space to deliver parcels, and KTX Cinema, which developed KTX No. 1 train cabin into a 'Moving First-run Movie Theater,' are examples of sales development in the early stages of construction. We have also actively developed tourism products to expand transportation demand. For instance, according to the ridership rate of KTX, seats with significantly increased discount rates are set as hard blocks, so we gained popularity by developing products such as the 'KTX Busan City Tour Dad Trip' with a travel agency.

The on-time train operation rate, considered an indicator of safe transportation and quality, has risen to the world's highest level. The International Union of Railways (UIC; Union Internationale des Chemins de Fer) standard for on-time train operation is that the delay in arriving at the final station is 15 minutes or less. Korail's customer service charter standards have strengthened management by limiting the delay in arrival at the final station to less than 5 minutes for KTX and 10 minutes for regular trains. KTX's 5-minute on-time rate remained at 86.4% for the first three months of operation but reached 95.5% within two years of opening.

The Customer Support System has also been strengthened, significantly expanding the railway customer center and improving the IT system to shorten call waiting times. We responded kindly to all inquiries and complaints, and compensation for high-speed train delays has also been increased to an unprecedented level. KTX provided a discount of 25% for delays of more than 20 minutes, 50% for delays of more than 40 minutes, and 100% for delays of more than 1 hour on the next ticket purchase; customer complaints were minimized when trains were delayed. We formed and operated a 'customer representative group' made up of customers from all walks of life at each branch and headquarters. Branch offices met once a quarter, and the head office met with customer representatives once a year to communicate and discuss improvement directions, so we upgraded our system for customer satisfaction.

Section 3 Development of Korea-type High-speed vehicle and KTX-Sancheon

Korea Railroad Corporation (passenger Project headquarters), considering that it takes more than three years to produce a new high-speed rolling stock, in 2006, decided to purchase 24 second-generation high-speed rolling stock (KTX-Ⅱ) to ensure delivery of high-speed rolling stock before the opening of the Gyeongbu high-speed railway's 2nd phase project. In order to operate efficiently and flexibly respond to demand on the Honam Line, Gyeongjeon Line, and Jeolla Line, which have small demand, rather than the Gyeongbu axis, which has high demand, KTX-Ⅱ requested to consist of 10 cars per train and to have a dual operation function that allows trains to be merged or separated at branch stations during operation. The reason for setting it to 10 cars per train was to ensure that the total train length did not deviate from the platform length of the high-speed railway stop station built for KTX during mid-train operation. In addition, KTX-II specified that all seats would be changed to rotatable seats to eliminate the backward-facing seats, which was pointed out as a complaint by KTX. When KTX-Ⅱ was introduced, the plan was to increase the ridership rate by turning 20 KTX cars per train operated by Honam Line Electrification to the Gyeongbu axis, which was scheduled to be operated at the time of the initial introduction plan.

In the KTX-Ⅱ international bidding ordered by Korea Railroad Corporation (technology headquarters), Hyundai Rotem, which participated in the test vehicle HSR-350x developed through the G7 high-speed Train Technology Development Project as the basic model, was selected by beating France Alstom, which supplied KTX, with high price competitiveness, so high-speed vehicle manufactured with Korean technology has been commercialized. The first batch of KTX-II vehicles was shipped in November 2008 and entered commissioning. As a result of a public contest held by Korail in February 2010, before the start of operation, it was named 'KTX-Sancheon' and was put into operation with six trains delivered first in March 2010.

The success of the Korea-type high-speed train development was made possible because government-funded researchers such as the Korea Institute of Machinery & Materials (KIMM) and Korea Electrotechnology Research Institute (KERI) made a recommendation to the Ministry of Science and Technology. In 1994, the 'High-speed Train Technology Development Project' was launched in 1994. According to the France TGV introduction contract, these researchers believed there was a limit to securing high-speed railway design technology through technology transfers alone. In April 1996, a government-wide high-speed Train Technology Development Project was planned in which the Ministry of Construction and Transportation, the Ministry of Commerce, Industry and Energy, and the Ministry of Science and Technology participated. It was confirmed as the Advanced Technology Development Project (G7 PROJECT) of the Ministry of Science and Technology. In December 1996, the project's first year began with High-speed Rail Construction

Corporation as the overall lead organization. In 1997, the project promotion system was reorganized, the overall management organization was changed to the Korea Railroad Research Institute, and the project system was streamlined. A number of domestic industry-academia-research institutions participated in this study, including government-funded research institutes, railway vehicle manufacturers, parts manufacturing companies, and universities supporting basic technology.

In June 2002, the G7 PROJECT was successfully completed, including the production of a 350 km/h prototype vehicle (HSR-350x) and commissioning on the Gyeongbu high-speed railway test line, and we continued to carry out the ‘High-speed Railway Technology Development Project’ with the objective of commercializing the development technology. During the commissioning process in December 2004, immediately after the opening of the Gyeongbu high-speed railway’s 1st phase, HSR-350x recorded a maximum speed of 352.4 km/h, achieving development objective and putting it on par with advanced countries in high-speed railway. The performance of the commercialized system was secured through a long-term durability test run of 209,406km until October 2007.

Section 4 The Emergence of High-speed Railway No.2 Operator, SR

Through seminars such as ‘Practice measures for introducing competition in the rail transport market’ held by The Korea Transport Institute in the second half of 2011, the Ministry of Land, Transport and Maritime Affairs confirmed the possibility of a policy to introduce competition into the railway operation business as a follow-up stage to the railway structural reform implemented in 2004, decided to promote this policy at the end of 2011. ‘KTX Measures to Introduce a Competitive System’ announced by the Ministry of Land, Transport and Maritime Affairs in its 2012 work report was, considering the preparation time for new operators, such as purchasing high-speed rolling stock and establishing operating systems, to open the operating rights of the high-speed railway from Suseo, which will open in 2015, to the private sector and complete the public offering for project candidates in the first half of the year.

When this policy was announced, the railway union began to promote opposition by framing it as ‘Conglomerate preferential treatment’ and ‘Railway Privatization.’ Unusually, Korea Railroad Corporation management also rebelled against government policy and even held an open debate between the Ministry of Land, Transport, and Maritime Affairs and its affiliated corporation. As public opinion for and against the policy sharply clashed, political circles, feeling burdened ahead of the general and presidential elections, requested the government to put the policy on hold. Since the order for high-speed vehicles could not be delayed, in late 2012, the government ordered the Korea Rail Network Corporation to purchase the first 22 high-speed vehicles planned for the Honam

High-speed Railway. Once an operator is selected in the future, it is decided to be leased to grant operating rights.

After the ruling party won the presidential election and the Park Geunhye Government came into power, the Ministry of Land, Infrastructure, and Transport's policy differed from the previous government's. It compromised with the Korea Railroad Corporation to introduce a limited competitive system by excluding private companies from participating in the operation of the high-speed railway from Suseo and establishing a subsidiary of the Korea Railroad Corporation. The railway union protested against this and went on the longest strike in history, but in December 2013, Korea Railroad Corporation established a subsidiary, Suseo High-speed Railway (Inc.) The Ministry of Land, Infrastructure and Transport issued a license for the high-speed railway Suseo~Busan and Suseo~Mokpo train operation business, resulting in the emergence of High-speed Railway No. 2 Operator. Suseo High-speed Railway (Inc.) changed its name to SR, Inc. in June of the following year.

Meanwhile, the completion of the Suseo-Pyeongtaek High-speed Railway line was delayed until the end of 2016, and the Honam High-speed Railway opened first in April 2015. The improved KTX-Sancheon 22 train delivered for the Honam high-speed railway was the first acquired and operated by the Korea Railroad Corporation and then leased to SR, Inc. when the Suseo-Pyeongtaek High-speed Railway line opened.

SR, Inc. operates the Gyeongbu·Honam high-speed railway line starting at Suseo Station. Dedicated stations include Suseo Station, Dongtan Station, and Jije Station on the Suseo~Pyeongtaek High-speed Railway line. In contrast, Gyeongbu axis' 8 High-speed Railway stations and Honam axis' 6 High-speed Railway stations are shared with Korea Railroad Corporation. The Korea Railroad Corporation released public stations and exceptions, and usage fees were determined through a separate agreement. Of the 32 high-speed vehicles (10 per vehicle) required to operate trains between Suseo-Busan and Suseo-Mokpo, 22 are leased with the Korea Railroad Corporation under a 5-year lease agreement. The remaining ten units were additionally purchased from Hyundai Rotem with the exact specifications. Vehicle maintenance mainly used at Gwangju high-speed vehicle depot was also entrusted to Korea Railroad Corporation. The ticket reservation and issuance system will also utilize the Korea Railroad Corporation's reservation and issuance system, but the two organizations will discuss specific operation plans with each other.

SR, Inc. began to differentiate its image by selecting the name 'SRT' for its high-speed train in February 2016 and announcing its BI (Brand Identity), reflecting the results of the public preference investigation. SRT means a train (SR Train) operated by SR, Inc. and a Super Rapid Train that travels quickly to its destination at 300 km per hour.

SR, Inc. was launched not only as an investment company with Korea Railroad Corporation as its largest shareholder but also as a company that outsources most of its work to Korea Railroad Corporation. Although many things could have been improved in introducing a truly competitive system, paying 50% of the track usage fee, which is much higher than Korea Railroad Corporation's KTX 34%, further helps repay the Corporation's construction debt. SRT fares were lowered by 10% compared to KTX, thereby increasing user benefits, operating at a surplus, and improving KTX's service. SR, Inc. was designated as an ‘other public institution’ in January 2018, and in 2019, it was upgraded to a ‘quasi-market public enterprise’ like the Korea Railroad Corporation.

Even after the launch of SR, Inc., the railway union continued to deny the effects of competition. It argued that it should be integrated into the Korea Railroad Corporation to eliminate inefficiencies such as overlapping costs and limitations in operating routes. The relatively union-friendly Moon Jae-in administration came into power, and the study on establishing the ‘4th railway industry development basic plan’ was reviewed by including an ‘evaluation of the competitive system of public enterprises.’ However, the government was replaced before a conclusion could be drawn, and the comprehensive opinion due to the review announced after the current government was inaugurated has limitations in analysis as the competitive system has been operating normally for only three years due to COVID-19 that occurred in early 2020. By reserving judgment on the maintenance or integration of the public enterprise competitive system, it gave strength to introducing competition.

In July 2023, the Ministry of Land, Infrastructure, and Transport strengthened its status as a public enterprise by investing in SR, Inc., securing 59% of the shares. We have begun a policy of expanding competition in railway operation, which is being implemented in many European countries, including issuing business licenses for the Jeolla Line and Gyeongjeon Line, which have been in high demand, to operate SRT from September 2023. SR, Inc., which was launched as a subsidiary of Korea Railroad Corporation and had limitations, now has the opportunity to strengthen its position as the No. 2 operator by establishing an operating system independent of Korea Railroad Corporation. Attention is being paid to whether Korea Railroad Corporation and SR, Inc. can raise the competitiveness of high-speed railways by one stage by improving railway efficiency and service through healthy competition.

| Figure 4-3 | Suseo Station

Source Korea National Railway (KR)

Section 5 Development of Operations such as 3rd Generation High-speed Rolling Stock KTX-Eum

Korea Railroad Research Institute succeeded in developing the second-generation high-speed test vehicle HSR-350x through the G7 PROJECT and the subsequent 'High-speed vehicles Technology Development Project.' To cope with changes in the international environment where demand for High-speed rolling stock is shifting to the electric multiple-unit method and to strengthen competitiveness in overseas markets, starting in November 2005, planning for next-generation High-speed Railway technology development began. After meeting and reviewing stakeholders, planning was completed in December 2006, and the next generation High-speed Railway Technology Development Project, an electric multiple unit type, high-speed train development project, began in July 2007.

About 50 industries, academia, and research institutes participated in this project, including Hyundai Rotem and Seoul National University, led by the Korea Railroad Research Institute and hosted by the Ministry of Land, Transport, and Maritime Affairs. It was carried out separately into the 1st phase (2007.7~2012.9) Project, Next Generation High-Speed Railway Technology

Development, and the 2nd phase (2012.11~2015.12) Project, 430km/h high-speed train (HEMU-430X) Commercialization Technology Development.

The initial objective of the next generation High-Speed Railway Technology Development Project was to develop an electric multiple unit type, high-speed train with a maximum test speed of 400 km/h (commercial speed 350 km/h), but it was designed to reflect the maximum speed record of foreign countries in 2011. In 2018, the highest test speed objective was raised to 430 km/h. The name of the high-speed train being developed is 'HEMU (High-speed Electric Multiple Unit)' which means '430km/h electric multiple unit type, High-speed Train test vehicle' and 430X (which means 430 km/h test train) 430km/h eXperimental) was added, and it was named HEMU-430X.

HEMU-430X distributes a propulsion system with an electric multiple unit type and design so that the maximum axle load of the existing power car type high-speed train is reduced by about 3 tons from 17 tons. This offsets the increase in track burden due to speed improvement. Since there is no power car at the front or rear, passengers can board the entire vehicle, allowing the capacity per train to be significantly increased compared to the KTX-Sancheon.

The weight of the vehicle body was reduced by 5% through the optimal design of aluminum extrusions, and sound insulation performance was improved by 3dB compared to the existing model. The onboard signal device is an integrated system that can be used in all signal systems of ATP, ATC, and ATS used in existing domestic lines and high-speed railway lines and was developed with pure Korean technology. In addition, we have developed a maximum speed of 430km/h independent bogie, a high-performance braking system, and a low-noise pantograph to apply an electric multiple unit type system. We have also developed passenger convenience facilities, including a passenger seat LCD information device using cutting-edge IT technology, a crew remote call service, automatic monitoring of the train cabin construction period using intelligent smart sensors, and restroom emergency detection notification.

Starting in June 2012, test runs started on the Gyeongbu high-speed railway line Dongdaegu⊠Busan section at an operation speed of 150 km/h, and performance verification and stabilization work was carried out through test runs at night when commercial trains were not running. HEMU-430X reached a maximum speed of 354.7 km/h in September 2012, breaking the HSR-350x's maximum speed record of 352.4 km/h set in December 2004 in seven years and nine months. Afterward, speed increase tests continued to reach the objective speed, and at the end of December 2012, the Gyeongbu high-speed railway line reached 401.4 km/h in the Ulsan⊠Gomo section, breaking the 400 km/h range. On March 28, 2013, the maximum speed increase test was completed by recording a maximum speed of 421 km/h. As a result, Korea became the country with the world's fourth fastest high-speed railway record, following France, Japan, and China, and opened a new era for the Korean high-speed railway. The reason why the speed increase test was completed at a speed lower than the development objective speed of 430 km/h is that, unlike foreign countries where most trials are conducted on long-distance straight sections, in Korea, the straight section is short at about 40 km due to topographical conditions, and air resistance is on open terrain. This is because many tunnels increased by about 30%, making it difficult to increase speed further. As a result of the simulation, it was predicted that if the test section was open terrain without a tunnel, a maximum speed of 444 km/h would be possible, and if the track conditions were the same as in France, the speed could increase to 466 km/h.

From July 2013, the Busan-Gwangmyeong section was run twice a week using the same driving method as the commercial train KTX, and tests were conducted to stabilize the system for practical use, improve major devices to improve performance, and check reliability. From December 2014, the infrastructure pilot section of the completed Honam high-speed railway line capable of operating at 400 km/h was operated at over 400 km/h, and performance confirmation tests were conducted on the facility.

The Next Generation High-speed Train HEMU-430X was tested through a total of 229 test runs and a driving distance of 121,123km until December 2015. Stability tests were performed, including the vehicle's driving stability, current collection quality, propulsion performance, and braking performance. As a result, the objective of stabilization was achieved by confirming that both international standards and the domestic Railway Safety Act standards were satisfied. The research achievements included winning the '2016 Korea Technology Grand Prize.'

Based on the developed HEMU-430X, in order to respond to the operator's demanded speed, we prepared specifications for commercialization models by dividing them by speed band; among these, the first 30 units of the HEMU-260 model were put into commercial use through the signing of a purchase contract with Korail in June 2016.

The commercialized HEMU-260 is a semi-high-speed vehicles with a maximum speed of 260 km/h. It has an aluminum vehicle body with six compartments and a seating capacity of 381. An entrance door for both high and low platforms was installed to increase operational elasticity and shortsen boarding and disembarking time

In August 2020, before full-scale operation, the semi-high-speed rolling stock HEMU-260 was named 'KTX-Eum' through a public contest. As of the end of 2021, 19 trains of KTX-Eum, with six cars per train, have been introduced and are in operation on the Gangneung Line, Jungang Line, and Jungbunaeryuk Line. In the future, 14 additional trains will be introduced in line with the high-speed conversion of the Gyeongjeon Line, Gyeongchun Line, and Chungbuk Line.

Meanwhile, in December 2016, Korail and Hyundai Rotem signed a purchase contract for 16 next-generation high-speed vehicles of the HEMU-320 model and entered the commissioning stage. Subsequently, Korail's 136 high-speed rolling stocks and SR, Inc.'s 112 high-speed vehicles ordered in early 2023 will be manufactured in the same format and run at a maximum design speed of 350 km/h and maximum sales speed of 320 km/h. Therefore, the next generation of high-speed electric multiple units developed with Korean technology will be commercialized.

Advances in high-speed railway operations have progressed across all areas, not just high-speed vehicles. When it first opened in 2004, KTX's usage performance was far behind regular trains, accounting for only 18% of the total trunk train performance. Ten years later, in 2014, the proportion increased to 42%, and in 2022, KTX alone, excluding SRT, reached 58%, showing that the central railway was reorganized around high-speed railways. This results from improvements in connected transportation means, service upgrades within stations and trains, and various marketing activities. As a representative example, the ticket issuance rate through mobile apps is recording an amazing performance of 83.8% for KTX and 86.9% for SRT in 2022 due to the development of Korail-talk and the continuous improvement of functions.

Maintenance technology for high-speed vehicles has also progressed from the 'reliability-centered maintenance (RCM)' established at the beginning of the opening of the high-speed railway, and innovation has continued to include the 'condition-based maintenance system (CBM)' and the promotion of 'Smart Factory' maintenance facilities. In the facility maintenance of the high-speed railway line, innovations were made, such as actively utilizing IT technology and taking proactive action through extensive data-based risk analysis. Thanks to these efforts, the safety of Korea's railways is ranked at the highest level in the world in objective measures such as the railway accident rate indicator.

| Figure 4-4 | Gangneung Station

Source Korea National Railway (KR)

05

KTX: 20 Years of History

Socio-Economic Change Due to High-speed Rail

05 Socio-Economic Change Due to High-speed Rail

Section 1 High-speed Railway and Changes in Life

Twenty years have passed since the high-speed railway appeared in this country, with many people's expectations. Even before the high-speed railway, general railways, passenger cars, express buses, and airplanes were operating between major regions. Some have questioned whether constructing a high-speed railroad involving an astronomical government budget was necessary. After much controversy and trial and error in Korea's high-speed railway from the initial planning stage to the construction process, the Gyeongbu High-speed Railway's 1st Phase section of the Seoul~Busan Line opened in April 2004. Afterward, there were successful High-speed Railway new line construction projects such as the Gyeongbu high-speed railway's 2nd phase section opening in 2010, Honam High-speed Railway's 1st phase section opening in 2015, Suseo-Pyeongtaek high-speed railway opening in 2016, etc. Also, we are continuously expanding high-speed train service by improving existing railway routes and operating high-speed trains such as Jeolla Line (2011), Gyeongjeon Line (2012), Gangneung Line (2017), Jungang Line (2021), etc.

The railway travel time between Seoul and Busan, which took 4 hours and 30 minutes before the Gyeongbu high-speed railway was operational, has now been reduced by approximately half to 2 hours and 25 minutes. Along with this reduction in travel time, looking at how the operation of the high-speed railway has changed our lives and what impact it has on the economic activities of the stopping area is an integral part of future High-speed Railway construction. It is meaningful for the promotion of operational policies, and considering that it takes a long time for the effects of transportation policy to be realized, today, 20 years after the opening of the High-speed Railway, is an appropriate time to start this work.

In this book, we will examine the impact of Korea's high-speed railway from social and economic aspects. First, we look at the characteristics of high-speed railway use along with changes in railway transportation performance, including high-speed railway. Next, we examine the social and economic impacts of high-speed railways from the following aspects: reduction of travel time and cost, Change in transportation mode share, reduction of environment, energy, and traffic accident costs, activation of exchange between people and goods, and long-distance commuting. , increase in commuting to school, improvement of image and competitiveness of stopping areas, revitalization of the local economy and balanced regional development, improvement of management balance of high-speed railway operating institutions, etc. In addition, we look at the results of academic discussions on the so-called 'straw effect,' the phenomenon of concentration in metropolitan areas due to high-speed railway construction, mainly argued by those who opposed some high-speed railway construction before the opening of the high-speed railway. This article used primary results from research reports, academic papers, and significant statistical collections published domestically and internationally. Some data have been updated to the latest data through additional analysis by the author.

Section 2 Socio-economic Impact of High-speed Railway

1. Reduction in Travel Time and Travel Costs

(1) Changes in Railway Operation Time

Gyeongbu Line & Honam Line

The 1st phase section of the Gyeongbu high-speed railway opened on April 1, 2004, and as a result, the high-speed train travel time on the Seoul~Busan Line was reduced to 2 hours and 45 minutes. Compared to the train travel time of 4 hours and 40 minutes before the opening of the High-speed Railway, the time was reduced by 1 hour and 55 minutes (42% compared to the original time). The Seoul~Mokpo Line takes approximately 3 hours and 10 minutes after the opening of the Gyeongbu high-speed railway's 1st phase. Hence, the time was shortened by 1 hour and 20 minutes (30%) compared to 4 hours and 30 minutes before opening.

With the opening of the Gyeongbu high-speed railway's 2nd phase section on November 1, 2010, all sections of the Seoul Station~Busan Station section except the Seoul Station~Gwangmyeong Station section were constructed as the new high-speed railway line. As a result, the railway travel time for the Seoul-Busan section was reduced by 2 hours and 25 minutes (52% shorter) compared to before the opening of the High-speed Railway and by about 30 minutes compared to when the 1st phase was opened.

On April 2, 2015, the Honam High-speed Railway’s 1st phase section, Osong~Gwangju Songjeong section, was opened. The high-speed train operation time of the Seoul-Mokpo Line is 2 hours and 30 minutes, which is 2 hours (44%) shorter than the 4 hours and 30 minutes before high-speed railway operation. The required time was shortened by 40 minutes compared to 3 hours and 10 minutes when high-speed trains operated using the existing Honam Line (2004.1 to 2015.4.2.).

Meanwhile, the Suseo-Pyeongtaek high-speed railway opened on December 9, 2016, but there is no significant difference in the time it takes to run the main sections of the Gyeongbu axis and the Honam axis. However, with the opening of the Suseo-Pyeongtaek High-speed Railway, accessibility to the southern part of the metropolitan area, including the Seoul Gangnam and Dongtan areas, has been dramatically improved.[7]

Express bus operation times[8] on the Gyeongbu and Honam axes vary by section but are approximately 75% to 94% of the Mugunghwa-ho bus. It was found that when express bus users switch to High-speed Railway, the travel time is reduced by 38% to 60% compared to the original express bus travel time.

Other Routes

With the opening of New Line High-speed Railway, including Gyeongbu High-speed Railway, Honam High-speed Railway, and Suseo-Pyeongtaek high-speed railway, Through the operation of high-speed railways on existing line sections such as the Jeolla Line, Gyeongjeon Line, Jungang Line, and Gangneung Line (including some New Lines), the travel time in the area has been significantly shortened to 37% to 67% of the existing level. The Express bus operation time[9] on the corresponding axis varies by section, but it was found that when Express bus users switch to High-speed Railway, the travel time is reduced by 6% to 33% compared to the original Express bus travel time.

Due to the high-speed railway operation, compared to when the high-speed railway was not in operation, the railway travel time was reduced by a total of 119,100 thousand hours as of 2019, and the reduction in time per person was analyzed to be 44 minutes.[10] Converting this to time value[11], it amounts to KRW 1.1151 trillion per year as of 2019, which can be seen as a time-saving benefit due to high-speed railway operation. Meanwhile, the time-saving benefit per person was analyzed to be 6,866 won.

(2) Comparison of Travel Time and Travel Cost with Other Means of Transportation

High-speed railway travel times are up to 30% shorter than the average of all land transportation methods, excluding airplanes, such as passenger cars, buses, and general railways, across all travel regions, but travel costs are analyzed to be 23-94.8% higher.[12] In the case of general travel cost, which converts travel time into cost by applying time value, the high-speed railway was found to

(7) High-speed train travel time between Suseo-Busan and Suseo-Mokpo takes 2 hours 10 minutes and 2 hours 30 minutes, respectively.

(8) Express bus travel time is 110 minutes from Seoul to Daejeon, 190 minutes from Seoul to Dongdaegu, 240 minutes from Seoul to Busan, 160 minutes from Yongsan to Iksan, 200 minutes from Yongsan to Gwangju, and 230 minutes from Yongsan to Mokpo.

(9) Express bus travel time is 139 minutes from Seoul-Gangneung, 185 minutes from Seoul-Donghae, 255 minutes from Yongsan-Yeosu, 215 minutes from Seoul-Jinju, and 160 minutes from Cheongnyangni-Andong.

(10) In case of non-operation of High-speed rail, the analysis was conducted on the assumption that Mugunghwa-ho and Saemaul trains would share the High-speed rail transportation performance in 2019.

(11) The time value was KRW 9,363 converted to the 2019 standard price based on data from the KDI Public Investment Management Center's 2nd preliminary feasibility study launch meeting in 2020 (National Area, October 2020).

(12) The analysis was conducted using the 2016 starting and ending point data where there is High-speed rail traffic that can be considered as an area where High-speed rail can be used.

secure competitiveness compared to the average of all transportation methods in sections over 200km. In other words, high-speed railways were found to secure competitiveness compared to other means of transportation in mid- to long-distance sections.

In major operating sections, airplane fares were found to be high at 147 to 191% of high-speed railway fares. The fares of Mugunghwa-ho, Saemaeul, and Express buses were found to be 46-59%, 71-87%, and 61-73% of High-speed Railway, respectively.

After the opening of the Gyeongbu high-speed railway in 2004, Korea's high-speed railway accessibility has been dramatically improved due to the additional construction and operation of high-speed railways such as the Honam high-speed railway and Suseo-Pyeongtaek High-speed Railway. The area accessible by high-speed railway within 60 minutes was 37.5% of the country's land area and 82.0% of the total population in 2004 but increased to 75.1% of the country's land area and 94.6% of the total population in 2021.

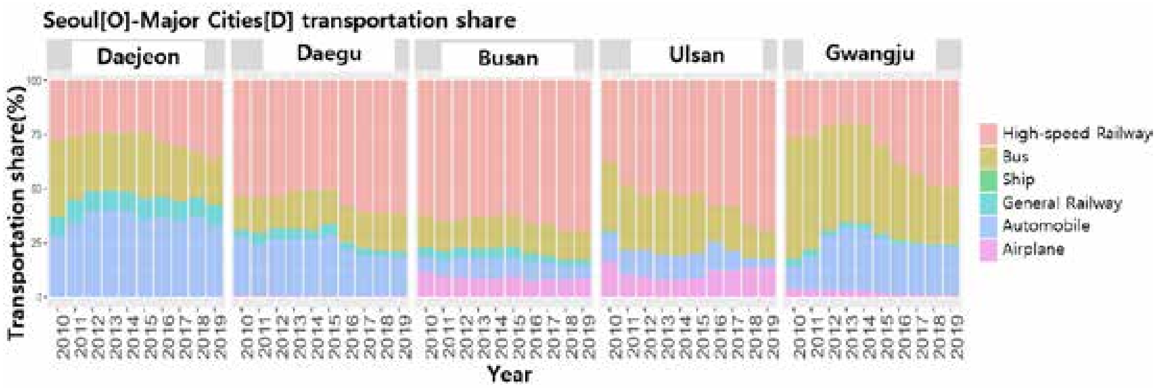
2. Increased Travel Distance and Number of Uses of High-speed Railway per Person

After the opening of the Gyeongbu High-speed Railway’s 1st phase in April 2004, through the continuous construction and operation of High-speed Railways such as the complete opening of the Gyeongbu High-speed Railway, Honam high-speed railway and Suseo-Pyeongtaek High-speed Railway, demand for high-speed railway use increased approximately 4.8 times from 19.79 million in 2004, the year of opening, to 94.88 million in 2019, the year before the impact of the coronavirus pandemic. The distance traveled per person increased approximately 3.7 times from 114.96 km/person in 2004 to 429.17 km/person in 2019, and the annual number of high-speed railway uses per person increased from 0.49 times/person in 2004 to 1.53 times/person in 2019. In 2020, when the impact of the coronavirus pandemic began to manifest, the high-speed railway travel distance per person was 264.99 km, a significant decrease of 62% compared to 429.17 km in 2019, and is gradually recovering from 2021.

3. Changes in the Transportation Sector Share Ratio

(1) Changes in Means Share between Seoul and Major Cities

The mode share of high-speed railways between Seoul and major cities gradually increases with the opening of additional high-speed railways. As the high-speed railway's share increased, the mode share of buses, passenger cars, general railways, and airplanes decreased, except for the passenger car share in the Seoul~Gwangju section. The high-speed railway share in the Seoul~Gwangju section increased the most from 26.4% in 2010 to 49.5% in 2019, while the bus share during the same period decreased significantly from 56.0% to 26.5%. As of 2019, the high-speed railway share of the Seoul~Busan Line was the highest at 62.1%, and the Seoul~Daejeon section was analyzed to be relatively low at 27.1%. This is because high-speed railways are competitive in long-distance areas.



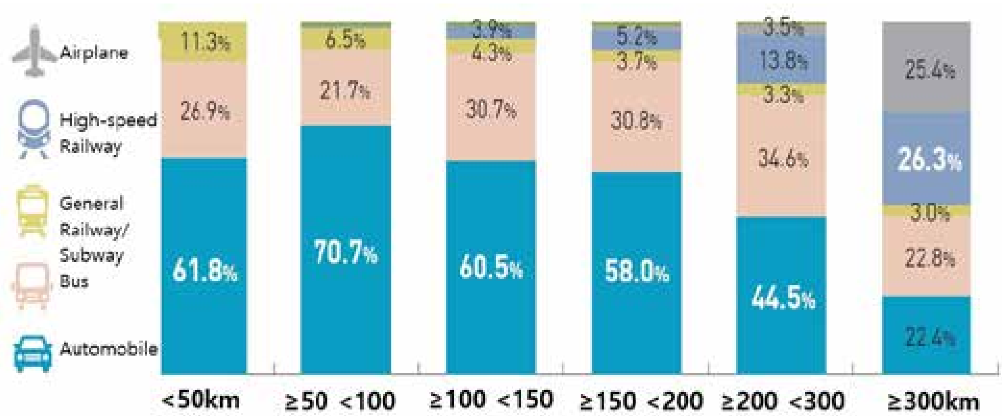
| Figure 5-1 | Changes in transportation share between Seoul and metropolitan cities

Source The Korea Transport Institute, National Transport DB Center (https://www.ktdb.go.kr), main means O/D between regions across the country

In particular, the airplane service between Seoul and Daegu was discontinued(13) in 2007 after the opening of the Gyeongbu high-speed railway, and this can be seen as an example that confirms the competitiveness of high-speed railways in mid-to-long distance sections.

(2) Status of High-speed Railway Share Ratio by Travel Distance

As of 2016, High-speed Railway's share rate for long-distance traffic over 300km was found to be 26.3%. It was found to be 13.8% in the 200~300km section and 9.1% in the 100-200km section. In the case of high-speed railways, the mode share ratio decreased sharply as the travel distance shortened. In particular, the mode share ratio was meager when the travel distance was less than 100 km.



| Figure 5-2 | Transportation mode share by travel distance (as of 2016)

Source National Transportation DB (2018), 『Passenger Traffic Status INDEX BOOK』

(13) In December 2017, the low-cost airline resumed operations and provided air service 5 days a week, but operations were suspended after the coronavirus outbreak.

4. Reduction in Environmental, Energy, and Traffic Accident Costs

Railways are known to be far superior to competing means such as passenger cars and buses in terms of environment, energy, and traffic accidents. The amount of carbon dioxide reduced due to high-speed railway operation is 238,433 tons as of 2019, which is analyzed to result in an environmental cost reduction of 231 won per year.[14] This is equivalent to the amount of carbon dioxide absorbed by approximately 3.79 million pine trees.

The energy efficiency of a high-speed railway is 18 times higher than that of an airplane, 10 times higher than that of a passenger car, and 3 times higher than that of a bus. The energy consumption intensity of a high-speed railway is 0.006 liters/person·km, which is 11 times more efficient than that of a passenger car at 0.067 liters/person·km. The energy savings benefit from high-speed railway operation was analyzed to be approximately 480 billion won as of 2019.[15]

The railway is considered a safe means of transportation with a lower frequency of traffic accidents than road transportation. As of 2019, the Expressway had a death rate of 0.2 per 100 million people·km, while the inter-regional railway had a death rate of 0.014, only 7% of the Expressway. Regarding the number of injuries, the inter-regional railway was 0.021 per 100 million people·km, which was only 0.23% of the 9.11 on the Expressway. The traffic accident reduction benefit due to high-speed railway operation was analyzed to be approximately 74.2 billion won as of 2019.

5. Impact of Social, Cultural, and Local Economic Aspects

Shortening travel times through high-speed railways promotes the inter-regional exchange of people and goods. Additional long-distance travel that would only have occurred after the high-speed railway operation occurs not only for cultural activities such as exhibitions, performances, and sports games but also for purposes such as shopping, medical care, tourism, meetings, and social gatherings. In addition, by promoting the exchange of people and goods, it also influences the economy of the high-speed railway stopping area.

(1) Promoting Exchange of People and Goods

The opening of the high-speed railway reduces the burden of distance and time for local city residents' cultural activities, tourism, and leisure activities[16], contributing to the increase in cultural

(14)It was assumed that 45% (calculated by referring to means sharing ratio data by distance group) of the demand (assuming that the demand obtained by subtracting the total rail demand in 2003 from the total rail demand in 2019 is the net increase in rail demand due to High-speed rail operation) for High-speed rail use was by passenger car, and the analysis was done by applying the carbon dioxide emission intensity of passenger cars (KDI, 2017) of 110g/km (based on a passenger car speed of 80 km/h) and the carbon dioxide cost intensity of 4.8 won/km (based on a passenger car speed of 80 km/h).

(15) Fuel costs are based on the average price of vehicle diesel in 2019.

(16) A survey in 2021 shows that 71.9% of High-speed rail users appear to perceive the opening of High-speed rail as having a positive impact on reducing the burden on long-distance tourism and leisure activities.

and tourism activities. The results of a survey conducted in 2021 also showed that the percentage of high-speed railway users who perceived the opening of high-speed railways as having a positive impact on expanding opportunities for local cultural activities was very high at 71.8%. Considering that 55.0% of respondents in a survey in 2010 said that high-speed railways have a positive effect on expanding opportunities for cultural activities, over the past 10 years, awareness of the positive impact of high-speed railways on cultural activities has strengthened.

As high-speed railways ease the burden of long-distance travel, baseball-viewing products using high-speed railways have emerged. The local government, where the high-speed railway stops, is launching various tourism products through close cooperation with the Korea Railroad Corporation to attract tourists. The local government and Korail are offering various tourism products using KTX. Some products have been shown to have good results, and examples are: 'Nong-turail KTX,' a train travel product that combines rural and tourism resources by Gangneung City, Gangwon-do, with Korail; 'Yeoju one-day local Tour by KTX' in Yeongju, Gyeongsangbuk-do; Products linking Cheonan-Asan Station KTX and City Tour bus, etc.

Additionally, 59.0% of high-speed railway users appeared to perceive that the opening of high-speed railways would make it easier to purchase products and services from other cities. This is an increase from the positive perception rate of 48.9% in 2010. In particular, in the case of stop stations located in small and medium-sized local cities, such as Iksan Station (68.0%) and Yeosu Expo Station (66.7%), the rate of positive perception was found to be higher.

Through KTX express delivery, which began in July 2005, New Line has also quickly supplied essential local specialties to consumers across the country. KTX express service is being provided at 14 stations nationwide as of the first half of 2023, including Seoul Station, Busan Station, Dongdaegu Station, Daejeon Station, and Osong Station on the Gyeongbu Line, and Yongsan Station, Iksan Station, and Yeosu Expo Station on the Honam Line.

According to the results of analyzing the status of international conferences held in each region from 2003 to 2008, while Seoul's average annual increase was only 4% during the same period, metropolitan cities where high-speed railways such as Busan, Daegu, Daejeon, Gwangju, and Ulsan stop showed an average annual increase of 14.9~103.6%. In particular, the growth rates of Gwangju City and Busan City were large at 103.6% and 49.7%, respectively, whereas, Incheon City, Gyeonggi-do, Chungcheongnam-do, and Gyeongsangnam-do showed a decrease in the number of international conferences held.

In 2003, more than 50% of all international events were held in Seoul, but in 2008, Seoul's hosting ratio decreased to 30.4%. In the case of Busan City, it increased significantly from 6.4% in 2003 to 22.5% in 2008, and Daejeon City and Gwangju City increased from 4.7% to 8.3% and 0.3% to 5.5%, respectively. Due to the improved accessibility of local cities due to the opening of the high-speed railway, there appears to be an increasing tendency to consider local cities when selecting venues for international conferences, conventions, seminars, etc.

(2) Long-distance Commuting, Increased Commuting to School

According to the results of a survey on High-speed Railway users, it was found that 67.0% of high-speed railway users perceived the opening of high-speed railways as having a positive impact on long-distance commuting and revitalizing school commuting. Iksan Station (84.0%), Yeosu Expo Station (83.3%), Mokpo Station (71.4%), Daejeon Station (65.7%), and Seoul Station (64.1%) showed the highest percentage of positive perceptions. It was found that more than 50% of positive evaluations were made at all stop stations.

In a survey investigation in 2010, while 54.9% perceived positively the impact of high-speed railways on long-distance commuting and revitalization of school commuting, in 2021, the proportion of users with positive opinions about the role of high-speed railways increased to 67.0%. This is likely because high-speed railway users have realized the influence of high-speed railways on long-distance commuting and the revitalization of school commuting through their past experiences.

The number of high-speed railway commuter Pass users, mainly for commuting and school travel, increased from 467,086 in 2004, the year the high-speed railway opened, to 4,283,695 in 2019, an increase of approximately 9.17 times. During the same period, the number of Saemaeul, Mugunghwa-ho, and Tongil Commuter Pass users decreased by approximately 0.95 times from 7,124,312 to 6,792,426. High-speed railways have contributed significantly to the increase in commuting and school traffic.

(3) Improving the Image and Competitiveness of the Stopping Area

According to a survey investigation conducted in 2021, the percentage of high-speed railway users who evaluated the opening of the high-speed railway as having a positive impact on improving the image of local cities was found to be 59.6%. Among the high-speed railway stop stations subject to the survey investigation, more than 50% of all stop station users except the objective station perceived that the opening of the high-speed railway positively impacted the image of local cities. In particular, for users of stop stations in some small and medium-sized cities, such as Yeosu Expo Station, Iksan Station, and Gangneung Station, the percentage of respondents who recognized that high-speed railways have a positive impact on improving the image of local cities (68.6% to 83.3%) was found to be significantly higher than that of large cities such as Seoul (54.4% to 64.7%). The results of the survey investigation in 2021 show results similar to the results of the survey investigation conducted in 2010.

According to a survey investigation conducted in 2020[17], the percentage of residents in areas

(17) In 2020, the Korea Transport Institute conducted a survey targeting 1,800 residents in the following areas: Busan Station (400 people), Dongdae Station (300 people), Daejeon Station (300 people), Gwangju Songjeong Station (300 people), Iksan Station (100 people), Mokpo Station (100 people), Jeonju Station (100 people), Suncheon Station (100 people), Gangneung Station (100 people)

where high-speed railway stops perceive that high-speed railways have had a positive impact on improving the competitiveness of the city was very high at 76.2%. Looking at the percentage of positive responses regarding the improvement of city competitiveness by high-speed railway by city subject to investigation, it shows: Gangneung City (85.0%), Daegu Metropolitan City (84.3%), Iksan City (79.0%), Suncheon City (79.0%), Daejeon Metropolitan City (76.3%), Mokpo City (75.0%), Busan Metropolitan City (74.0%), Gwangju Metropolitan City (70.7%), Jeonju City (63.0%).[18]

The percentage of people who recognized that high-speed railways positively impacted the development of local tourism and leisure industries was the highest at 78.1%. In addition, local industry development (71.9%), local culture and entertainment development (71.2%), local wholesale and retail distribution development (64.2%), job creation (50.3%), revitalizing the real estate market (49.8%), health care advancement (47.0%), local education development (45.3%), and population increase (41.0%).

In particular, local small and medium-sized cities such as Gangneung City, Jeonju City, and Suncheon City were found to perceive the high-speed railway as having a significant influence in strengthening local tourism and leisure, local industry development, and local culture and entertainment sector competitiveness. In the case of special and metropolitan cities, it has been investigated that high-speed railways significantly impact local tourism and leisure, local industry development, and strengthening local culture and entertainment sector competitiveness. The positive response rate was found to be lower compared to small and medium-sized local cities.

(4) Revitalizing the Local Economy and Supporting Balanced Regional Development

Survey Investigation Results

According to a survey investigation conducted in 2021, high-speed railway users recognized that the opening of the high-speed railway has a positive impact on revitalizing the local economy at 57.7%, which was higher than the neutral opinion of 32.0% and the opinion of no relevance at 10.3%.

In addition, 59.5% of high-speed railway users perceived the opening of high-speed railways to have a positive impact on balanced regional development. The positive perception rate of 59.5% for the High-speed Railway shown in the 2021 investigation is much higher than the positive perception rate of 45.3% in 2010, at the beginning of the High-speed Railway's opening.[19] It is judged that this is due to the fact that the positive aspects of high-speed railways on balanced regional development

(18) Those who did not answer that High-speed rail has a positive effect are in the position that High-speed rail cannot be seen to have a positive effect on urban competitiveness. This does not mean that High-speed rail will have a negative impact on city competitiveness.

(19) The 2010 survey was conducted on residents of Daejeon, Daegu, and Busan, and this may raise questions about whether it is reasonable to directly compare the results of the two surveys, as the survey area and survey subjects are somewhat different from 2021. However, even when comparing the results of two surveys targeting the Daejeon, Daegu, and Busan regions, which are commonly included in 2010 and 2021, the positive perception rate in the 2021 survey results was 54.6%, which was greater than the 45.3% in 2010. The 2010 survey showed that the positive recognition rates for balanced regional development among residents of Daejeon, Daegu, and Busan were 45.5%, 46.4%, and 44.3%, respectively.

have been sufficiently imprinted on users through over 10 years of experience using high-speed railways and observation of the impact of high-speed railways on balanced regional development. It is judged.

Activation of Station Influence Area Development

Through high-speed railway construction, station influence area development, such as land development near major stop stations and construction of industrial and commercial facilities, is actively taking place. Gwangmyeong Station and Cheonan-Asan Station are examples of successful land development projects near high-speed railway stop stations. The Gwangmyeong Station land development project developed a mini-new city-level city with over 9,000 apartments, residential-commercial complexes, commercial facilities, neighborhood living facilities, and parks on a 1,956,000 ㎡ site in Iljik-dong and Sohak-dong of Gwangmyeong City and Seoksu-dong and Bakdal-dong of Anyang City. In addition, the development of station-influence areas such as comprehensive transfer centers, large distribution centers, and hotels was promoted, and the appearance of the Gwangmyeong Station area has been dramatically transformed through the construction of a high-speed railroad, including the operation of the city airport terminal since January 2018.

In the case of Cheonan-Asan Station, as an example of a land development project, the Asan Baebang District land development project, which is the Asan New Town 1st phase development project, was completed in 2012, and not only the Asan Baebang district but also extensive commercial facilities have been built near Cheonan-Asan Station. The Asan Tangjeong District Development Project, the 2nd phase project, is being promoted with a partially reduced project size and is planned to be completed by 2027. The plan is to encourage the construction of an international exhibition and convention center and the development of a residential area.

In the case of Dongdaegu Station, a complex transfer center and large-scale commercial facilities were created using private capital. Through this, the high-speed railway station was able to function not only as a transportation node but also as a shopping function. In addition, the construction of complex transfer centers, business and commercial facilities, and cultural facilities is being promoted for most high-speed railway stop stations such as Daejeon Station, Singyeongju Station, Ulsan Station, Gimcheon-Gumi Station, and Busan Station.

In particular, Osong Station is the only high-speed railway branch in Korea where the Gyeongbu high-speed railway and Honam high-speed railway meet. Before the opening of the High-speed Railway, the name Osong was unfamiliar to most people. As the high-speed railway stopped, awareness increased. Around the Osong Station influence area, we are pursuing the construction of commercial and cultural facilities, residential facilities, exhibition and distribution facilities, industrial facilities, and lodging facilities on a 555,000㎡ site.

Land Value Change Trend

After the opening of the high-speed railway (2004-2009), the average annual land value change rate of 3.15% in the stopping area decreased slightly compared to 3.65% before the opening of the High-speed Railway. Still, it was higher than the national land value change rate of 1.34% from 2004 to 2009. Compared to before the opening of the high-speed railway, the nationwide land value decreased by 1.57% after the opening. In contrast, the land value of the high-speed railway stopping area decreased by only 0.5%. However, it isn't easy to interpret the increase in land value in places where high-speed railways stop as solely due to the operation of high-speed railways. The argument that the construction and operation of high-speed railways contributed to increased land values in stopping areas is somewhat persuasive.

According to domestic-related studies (Hong Gil-Ho, 2018; Seo Eun-Young, 2014), the officially announced land value of the high-speed railway stopping area was found to increase after the opening of the High-speed Railway. Except for some stopping areas, the overall land value increase rate was found to be higher than the national average. In a study that examined changes in apartment prices in the Daejeon area following the opening of the high-speed railway (Go Young-Seon, 2013), due to the opening of the high-speed railway, apartment prices in the station influence area were analyzed to have a higher rate of increase compared to non-station influence area areas.

Changes in Population and Number of Workers

After 2011, Korea's population growth rate, compared to the previous year, showed an increasing trend until 2015. After that, the growth rate gradually decreased and has been showing negative values since 2018. While the population growth pattern of cities without High-speed Railway stops is similar to the national average, the Korea Rail Network Corporation found that in cities where high-speed railways stop, the population growth rate is more gradual than in cities where high-speed railways do not stop. According to the results of analyzing the population increase and decrease before and after the opening of each city where the high-speed railway stops (Han, 2020), no significant population increase or decrease was confirmed between cities where the high-speed railway stops and cities where it does not. According to the analysis results to date, the impact of high-speed railways on the population increase or decrease in cities where they stop is judged to be limited. In reviewing this, it is judged desirable to determine the impact through the use of long-term time series data in the future. Meanwhile, in overseas cases (World Bank, 2014), there are cases where the population growth rate in some stopping areas of the Japan high-speed railway was reported to be higher than the national average. Still, the causal relationship between high-speed railway stops and population growth is unclear.

According to a review of the rate of change in the number of employees from 2007 to 2020, it is judged to be difficult to identify meaningful differences between cities where high-speed railways stop and cities where they do not stop.

GRDP Changes

According to the results of reviewing the change in per capita GRDP since 2015 in cities where high-speed railways stop and cities where they do not stop, stationary cities had a higher per capita GRDP than non-stationary cities. As of 2019, the GRDP per capita of stationary cities was approximately 3.4% higher than that of non-stationary cities. In the case of Germany (World Bank, 2014), the GRDP of high-speed railway stopping areas was higher than that of non-stopping areas. However, what needs to be clarified is whether the relatively high GRDP of these high-speed railway-stopping cities is due to stopping the high-speed railway or whether this result may have been obtained because the high-speed railway stopped in an area where GRDP was inherently high or increasing. Alternatively, this result may have been obtained because the high-speed railway stopped in an area where GRDP was inherently high or increasing.

6. Improving Management Balance of Railway Operating Organizations

High-speed Railway transportation income more than tripled from KRW 837.5 billion in 2005 to KRW 2.6146 billion in 2019. During the same period, Korail's passenger transportation revenue increased from KRW 1.8517 trillion to KRW 4.0575 trillion. High-speed Railway's share of passenger transportation revenue increased by 19.2% from 45.2% in 2005 to 64.4% in 2019.

The operating profit of Korail, which operates KTX, was in the red until 2013, recording a deficit of KRW 737.4 billion in 2008. Due to the rapid increase in KTX FARE income, operating profit and loss recorded a surplus between 2014 and 2016. Although it has been recording operating losses since 2017, the operating loss in 2019 was KRW 144.6 billion, a significant decrease compared to KRW 538 billion in 2005, at the opening of the High-speed Railway. During the same period, high-speed railway transportation revenue more than tripled from KRW 837.5 billion to KRW 2,614.6 billion, which is assessed to have significantly improved Korail's management balance. Meanwhile, SR, Inc.'s High-speed Railway operating profit recorded a surplus of 32.7 billion won as of 2019. During the same period, high-speed railway transportation revenue more than tripled from KRW 837.5 billion to KRW 2,614.6 billion, assessed to have played a major role in improving Korail's management balance. Meanwhile, SR, Inc.'s High-speed Railway operating profit recorded a surplus of 32.7 billion won as of 2019.

Section 3 Conclusion

After the opening of the Gyeongbu high-speed railway in April 2004, with the introduction of the Honam high-speed railway and Suseo-Pyeongtaek High-speed Railway, the railway travel time on major transportation axes such as Seoul~Busan has been reduced to about half compared to before the opening of the high-speed railway. Through this speed competitiveness and relatively competitive fare policy, the high-speed railway is establishing itself as a central means of transportation in Korea's medium- and long-distance travel. As of 2019, the high-speed railway share of the Seoul~Busan and Seoul~Gwangju sections was 62.1% and 49.5%, respectively, which were significantly higher than other transportation methods. In particular, airplane service between Seoul and Daegu was discontinued in 2007 due to the opening of the Gyeongbu high-speed railway. Demand for using the high-speed railway increased 4.8 times from 19.79 million passengers at the beginning of its opening to 94.88 million passengers in 2019. The distance used by high-speed railways per person increased 3.7 times from 114.96km to 429.17km during the same period. The area accessible to the high-speed railway within 60 minutes increased from 48.1% of the total land area at the beginning of the high-speed railway opening to 74.5% in 2018, hence the accessibility of high-speed railways has been greatly improved nationwide.

As a result of reviewing and analyzing major research results and statistical data so far, the high-speed railway is judged to have an overall positive impact on the local economy and social and cultural aspects. Professional baseball viewing products and local travel products using high-speed railways have appeared, and delivery of local specialties through high-speed railways has become active. high-speed railways have been shown to significantly contribute to revitalizing exchanges between people and goods, including an increase in the number of meetings held in areas where high-speed railways stop. The number of high-speed railway Commuter Pass users in 2019 increased about 9 times compared to 2004, the year the high-speed railway opened, and long-distance commuting and commuting to school have increased significantly due to the high-speed railway.

In addition, according to the perception of high-speed railway users, the high-speed railway has a positive impact on improving the image and competitiveness of the area where it stops, including the development of local tourism and leisure, development of local industry, development of local culture and entertainment, and revitalization of local wholesale, retail, and distribution. Through high-speed railway construction, station influence area development, such as land development and industrial and commercial facility construction in areas near major stop stations, is being actively promoted. Gwangmyeong Station and Cheonan-Asan Station are examples of successful land development projects near high-speed railway stop stations. In the case of Dongdaegu Station, a complex transfer center and large-scale commercial facilities were created using private capital. In addition, the construction of complex transfer centers, business and commercial facilities, and cultural facilities are being promoted for most high-speed railway stop stations such as Daejeon Station, Singyeongju Station, Ulsan Station, Gimcheon Gumi Station, and Busan Station.

In addition, the high-speed railway is advantageous in terms of energy, environment, and traffic accidents compared to competing means of transportation, contributing to reducing social costs and improving the management balance of the Korea Railroad Corporation. There are cases where the growth rate of some social and economic indicators such as population, number of employees, and GRDP in areas where High-speed Railway stops are higher than in non-stop areas, but it is judged that the mutual causal relationship between high-speed railways and changes in these social and economic indicators will need to be further investigated using long-term time series data in the future.

As examined in this article, high-speed railways are already deeply entrenched in the daily lives of our people and are believed to have a significant impact on economic activities in related regions. However, it is necessary to recognize that high-speed railways may be a necessary condition for regional development, but not a sufficient condition, and it is believed that active efforts by related organizations will be needed to ensure that high-speed railways can become a catalyst for regional development in the future.

06

KTX: 20 Years of History

The Future of Korea’s High-speed Railway

06 The Future of Korea's High-speed Railway

Section 1 World High-speed Railways and Korea High-speed Railway

The world's highest-speed railway began operating in 1964 on a 515km section between Tokyo and Osaka. In the case of Europe, in 1981, France started operating the 390km section between Paris and Lyon. Germany began its high-speed railway by opening the Mannheim-Stuttgart section in 1991. Each country has constructed High-speed Rail Construction to improve the speed of existing lines due to capacity saturation, new route construction, and connection to underprivileged areas.

The operation speed of the railway progressed more than twice as fast as the passage of time. The speed of 130 km/h in 1934 will increase to 200 km/h in 1964 and 500 km/h in 2027. Speed has increased by 70 km in 30 years and by 300 km over 60 years. Accordingly, the space for movement is expanding in proportion to the increase in speed. The economic growth of the three East Asian countries and high-speed railway construction and operation are very closely related. Korea achieved a high level of economic growth from the late 1960s to the 1990s, and then suffered a financial crisis in 1997 and underwent restructuring through conditional fund management with the IMF. Since then, it has maintained stable growth. China has been recording high economic growth since implementing the reform and opening policy in 1978. Japan achieved high economic growth from the late 1950s to the 1980s. However, Japan's economic growth rate has recently slowed due to structural problems such as population aging. Korea's High-speed railway opened on April 1, 2004, and 19 years have now passed. As the world's fifth country to operate a high-speed railway, Korea has grown significantly in many ways, including increased transportation volume and regional development. The start of construction in 1992 was also a result of a decision to consider future transportation. In the case of Korea's Gyeongbu High-speed railway, it was due to the saturation of the capacity of existing lines, and the construction of the Honam high-speed railway is mainly due to regional development and balanced national development. high-speed railways in Japan and China are promoting balanced national development by connecting underprivileged areas and economic growth through new routes due to the saturation of existing line capacity. Recently, Japan has been steadily pursuing a plan to connect Kyushu and Hokkaido, areas with no demand, and the East Sea region of Japan, with a policy of expanding high-speed railways throughout the country. While focusing on high-speed railways, we are promoting travel between major hubs in a country spanning 3,000km horizontally within 3 hours. In addition, it shows high-speed and technological advancements, including the linear Shinkansen, which opens in 2028 and can reach speeds of over 500 km/h. China's High-speed Railway is planned to connect the entire country with high-speed railways after the opening of the high-speed railway in 2008. Currently, it is contributing significantly to creating a unified China with the world's largest high-speed railway network and a speed of 350 km/h. In addition, the company is focusing its efforts on exporting its high-speed railway to the world.

China Railway is leading economic development by revitalizing the local economy, meeting people, and mobility exchanges. Additionally, personnel movement, freight transportation, and high-speed railway infrastructure promote domestic labor employment and the development of related companies. The level of construction and technological advancement of the high-speed railway is helping to export China's high-speed railway, raise awareness of China's high-speed railway, and generate foreign currency income. Now, the Korean railway will mark its 20th anniversary in 2024 by opening a high-speed railway following Japan. In this book, we will compare Korea, which is continuously developing East Asia's High-speed Railway, with Japan, which opened first, and the three countries with the world's longest High-speed Railway and consider the direction of Korea's development.

Section 2 Characteristics and Development of Korea High-speed Railway

The function of the railway is to transport passengers and freight as quickly, safely, and efficiently as possible. The standards for policy decisions to carry out this include safety, efficiency, legality, and cultural values. Korea's high-speed railway will celebrate its 20th anniversary in 2024, and it is vital to mention its development process and achievements briefly.

The most prominent characteristic is that Korea's high-speed railway operates in a relatively small country, which paradoxically has a significant effect. Station-influence areas and cities are developing around stop stations, and representative examples include Gwangmyeong, Cheonan-Asan, and Osong.

In the case of other stop stations, the influence is as much as 70km based on the station. The High-speed Railway's influence area at Cheonan-Asan Station extends to Cheongju, Yesan, and Dangjin.

Looking at the results of Kim Young-min's Ph.D. thesis in 2023, according to the results of analyzing residential movement characteristics after high-speed railway station-influence area development in Cheonan City, Buljeong-dong, a high-speed railway station-influence area, and in Gimcheon City, in Yulgok-dong, the number of residents is very high, citing convenient transportation facilities and location environment as reasons for moving. In addition, high-speed railways are also operated on conventional line sections, and it is possible to travel quickly across the country through high-speed trains, such as the high-speed railway to Gangneung and the high-speed joint train on the Jungang Line.

The high-speed railway operation served as an opportunity for the development of the area around the stop station but also led to the concentration of the metropolitan area. Although the populations of Daegu and Busan have decreased, migration to the metropolitan area is intensifying, and the metropolitan area GRDP is increasing. Of course, factors other than transportation also contribute to the deepening of the metropolitan area. Verification of the straw effect of high-speed railways is also a future project that must be conducted more thoroughly. One thing that must be mentioned in the development of Korea's high-speed railway is that the Saemaul-ho, which had a maximum speed of 140km at the time of opening in 2004, was decided to operate at a maximum operating speed of 300km, which had the insight to see the future 10 or 20 years later.

Although there have been discussions about high-speed development since the 1970s, we must also remember the decisiveness and driving force of the decision-maker group that promoted this in earnest in the late 1980s.

Korea's high-speed railway overcame many difficulties, from the basic plan established in 1989 to its opening in 2004. The introduction of high-speed railways in Korea was launched in the socio-economic environment of high economic growth and high social costs due to automobiles in the 1960s and 1970s. First, as mentioned earlier, Korea's economic growth is based on the active use of foreign capital and consistent efforts to improve the speed of rail transportation.

In fact, Korea's economic growth rate in the 1960s was 9.5%, 9.3% in 1970, and 9.9% in 1980. The number of automobiles increased 5.4 times from 1990 to 1980, from 500,000 in 1980 to 1 million in 1985 and to 2.7 million in 1990. In particular, the Middle East boom in the 1970s and 1980s allowed our economy to grow rapidly.

The efforts of overseas investigation teams and domestic researchers became the basis for introducing high-speed railways. In relation to the introduction of railway foreign loans in 1973, the World Bank (IBRD) commissioned research from technology researchers in France and Japan to prepare long-term measures for transportation difficulties between Seoul and Busan. They proposed the construction of a new railway on the Gyeongbu axis. Afterward, through several studies and investigations, including a study by the Korea Institute of Science and Technology (KIST) in 1978 and a joint feasibility study with Korea-USA-Denmark in 1983, the need for the Gyeongbu high-speed railway was suggested and discussed.

What must be mentioned in the development history of Korea's high-speed railway is that there were efforts to improve speed before the high-speed railway and the maximum speed of 140 km/h class train began operation on July 6, 1987. The person who promoted this was then President Choi Gi-Deok of the Korean National Railroad (in office from 1983 to 1988).

At the time of the high-speed railway plan, it was decided to change Saemaul-ho operation from a maximum speed of 140 km to a maximum operating speed of 300 km and had the insight to see the future 10 to 20 years from now.

There has been discussion about high-speed conversion since the 1970s, but we must also remember the decisiveness and driving force of the decision-maker group that promoted this in earnest in the late 1980s.

There were many people, but the person I would like to mention is Minister of Transportation Kim Chang-geun, who was the key figure in deciding to promote the high-speed railway at the time.

Minister Kim is a four-term politician from Andong, Gyeongsangbuk-do. He studied in the Philippines and the USA. He briefly served as Minister of Transportation for about one year and three months from December 5, 1988, to March 18, 1990. The plan for the High-speed Railway, which created a new future for Korea's transportation, was completed during his tenure. Minister Kim said that on March 18, 1989, regarding the Gyeongbu high-speed railway, construction began in August 1991. In 1998, it was announced that the plan to operate to Busan in less than 2 hours by high-speed railway was finalized and promoted. Based on this, a high-speed railway planning team was created, and the foundation for construction was laid. However, Minister Kim, who promoted this, unfortunately, passed away on August 1, 1991.

Section 3 Characteristics and Development of Japan's High-speed Railway

Shinkansen opened in October 1964 to coincide with the Olympics. The opening of the Shinkansen began at the Railway Technology Institute (RTRI), where airplane researchers gathered at the institute following the USA's decision to ban airplane production after World War II. We began building a high-speed railway based on pre-war railway vehicle technology.

Japan's high-speed railway, the Shinkansen route, passes through the major cities of Tokyo, Nagoya, and Osaka and has short distances between stations, making it a highly sought-after route. The vehicle type has an electric multiple-unit structure, unidirectional operation, and transports only passengers. This electric multiple-unit vehicle was promoted based on the success of previous tank operations. Because of this, independent technology development became possible. To meet the opening date, a test drive of 120,000km, shorter than France's 1 million km, was conducted, so it suffered from initial operation difficulties. Shinkansen is operated under standard gauge, but this has the disadvantage of making direct operation difficult because the existing lines of Japan Railway are narrow gauge.

Looking at Japan's High-speed railway influence, these are the following:

First, looking back now, almost 60 years later, it has contributed to decentralization and regional development. Nevertheless, the phenomenon of centralization and concentration in Tokyo is still occurring, which is due to the working together of other factors such as politics, economy, and culture. In the case of Tsukuba City near Tokyo, many people live in Tokyo and work in Tsukuba City even though high-speed trains have been built.

Recently, the area has been expanding, with the opening of the Shinkansen to Kyushu and Hokkaido. However, demand is lower than that of East Japan, West Japan, and Tokai Shinkansen, so issues such as operation and safety measures in areas with much snow are emerging. At the same time, population decline is causing deficits on local lines and differences between profitable and non-profitable companies, and there are concerns that the influence of overly segmented spin-offs may be halved. In addition, problems with the operation of parallel conventional lines due to Shinkansen and the operation of cargo Shinkansen (Hokkaido Shinkansen) are being raised.

The Shinkansen traffic volume ratio, which accounts for the total traffic volume (persons/kilometers) of each JR company that operates Shinkansen, is comprised of JR East Japan 23%, JRTokai 84%, JR West Japan 32%, and JRKyushu 20%. The table below shows railways vs. major cities with active Shinkansen transportation. It displays the airplane's share ratio (based on the number of people transported). The demand for airplanes is overwhelmingly great between Tokyo and Fukuoka and Osaka and Kagoshima, which are about 1,000 km away, but between Tokyo and Hiroshima and Nagoya and Fukuoka, which are about 800 km long and take 4 hours by Shinkansen, the demand for both means of transportation is almost the same. When it is less than this distance, the demand for railway transportation is much greater, so the influence of the Shinkansen can be confirmed.

| Table 6-1 | In major sections where the Shinkansen can be used, Railway vs. Airplane transportation demand market share

Section	Service km	Railway	Airplane
Tokyo~Nagoya	366km	100	0
Tokyo~Osaka	553km	85	15
Tokyo~Aomori	714km	78	22
Tokyo~Okayama	733km	70	30
Tokyo~Hiroshima	894km	68	32
Tokyo~Fukuoka	1,175km	7	93

Data: West Japan (JR West Japan) data and East Japanrailway data (2020) read through data

With the opening of Shinkansen, many airplane routes were abolished. High-speed railways are most competitive in the 300-500km section, and it can be seen that competitiveness is high in the operating time of two to three hours.

| Table 6-2 | Major air routes discontinued following the opening of the Shinkansen

Route	Alternative Shinkansen
Tokyo ~ Nagoya (366km)	Tokaido Shinkansen
Tokyo ~ Sendai(351.8km)	Dohoku Shinkansen
Tokyo ~ Nigata(333.9Km)	Joetsu Shinkansen
Nagoya ~ Hiroshima(528.2km)	Tokaido & Sanyo Shinkansen
Osaka ~ Yamaguchi(474.4km)	Sanyo Shinkansen

Most passengers are on business trips, about 70%, and if commuting and office workers returning home on the weekend are included, the number reaches 75%.

Second, although there is not much demand, especially in Japan, there is a Seibi(整備) Shinkansen system for balanced regional development and revitalization of the region. In 1970, the Seibi Shinkansen Railway Maintenance Act was enacted, and based on this, the Kyushu Shinkansen and others were opened to revitalize the region.

The primary direction of the Seibi Shinkansen is to reach major cities within 3 hours and operate at a speed of over 120km on the conventional line section and over 200km on the New Line section (maximum speed 260km). The financial resources are approximately 1/3 from the central government (covered by Shinkansen transfer revenue and public project costs), 1/3 from local governments (covered by local allocation taxes), and 1/3 from usage fees from the operating company. The economic feasibility of Seibi Shinkansen reaches B/C of 2.4 to 2.6, considering regional development effects. The main promotion areas are the Hokkaido, Kyushu, and Northeast regions.

In the case of linear Shinkansen, which is scheduled to open third, securing profitability is becoming a key issue due to difficulties in mass transportation and separate route operations.

The railway draws the big picture, keeping in mind that the travel time is up to 4 hours longer than that of an airplane. The Japanese maglev train, Central Shinkansen, was designed to be a train that would emerge in December 1964, immediately after the opening of Shinkansen, based on the "National Shinkansen Railway Maintenance Act."

After that, it took 40 years from the basic plan to approval of the implementation plan. After the basic plan in 1973, investigation and test operations, including topography and geology, were conducted from 1974 to 2008. On February 24, 2010, the transportation policy council gave the following advice on 「Nomination of sales entity and construction entity and decision on maintenance plan」. It gave the advice that 「It would be better to use JR Tokai as the sales and construction entity, superconductivity linear as the driving method, and the Southern Alps Route as the route.」

Under this advisory, on 26 May 2011, what was decided was that the driving method would be superconductivity maglev, the maximum design speed would be 505 km/h, the route would pass through the central region of Tokyo and Osaka, and the construction cost would be 9.03 trillion yen.

Construction costs are covered by long-term, fixed, low-interest rate loans provided by the Japanese government through the Railroad Transportation Facilities Organization. Completion of Tokyo-Nagoya is scheduled for 2027. During this period, there will be no principal repayment from JRTokai, and the principal and interest will be repaid equally over the next ten years. They will be repaid with income during this period. Through this, the time between Tokyo and Osaka will be shortened to 67 minutes, and the growth power of the three major metropolitan areas is expected to spread nationwide.

Japan has been making efforts to utilize High-speed Railways. Japan's high-speed railway has three strategies. That is 10,000 yen, 4 hours, and 30 days. The one-way fare from Tokyo to Osaka, a representative route, must be less than 10,000 yen, it must be possible to operate anywhere in the country within 4 hours, and reservations must be possible up to 30 days in advance.

In the case of Tokyo-Osaka, the discount rate for airfare is less than 10,000 yen, the regular fare for the Shinkansen is 13,850 yen, and even with a discount, the railway fare is 11,230 yen. Compared with the waiting time of an airplane, the time is about 3 hours, which is similar to that of a railway. Therefore, for railways to be more competitive in fares, they must be lowered below 10,000 yen.

Additionally, the 4-hour rule states that competitiveness can be achieved when you arrive anywhere in the country by rail within 4 hours. This is the time to reach the destination, so even if you transfer, the railway can have an advantage over other transportation methods if it has time competitiveness.

In fact, there is overwhelming demand for airplanes between Tokyo and Fukuoka and Osaka and Kagoshima, which are distances of around 1,000 km. In the 800km Shinkansen 4-hour section from Tokyo to Hiroshima and Nagoya to Fukuoka, the demand for both means of transportation is almost the same. When the distance is shorter than this, the demand for railway transportation is much greater, so the influence of the Shinkansen can be confirmed, and even if a connecting vehicle is used, the railway can have competitiveness if it is less than 4 hours.

Demand for high-speed railways continues to increase through continued efforts to reduce fares, improve speed, and provide smooth, connected transportation. For Japan's High-speed Railway, urban plans, shopping districts in front of the station development, and large-scale land development, which are implemented as incidental projects for revenue development of railway companies, ultimately serve as the core infrastructure of regional development. This places particular emphasis on growth in connection with tourism resources. In addition, the railway is very dominant in the public transport share, and especially in the competitive structure with the airplanes, it is vastly superior in competitiveness in terms of safety, speed, convenience, fare level, and comfort. Meanwhile, Japan's investment financing structure, in which national and local finances share a certain percentage in Seibi Shinkansen's financial resources structure, also has significant implications for us.

Section 4 Characteristics and Development of China's High- speed Railways

As for high-speed railways, Japan's Shinkansen High-speed Railway opened in the 1960s, and high-speed railways rapidly increased in Western countries in the 1990s. In 1992, with the adoption of the 'Beijing~Shanghai High-speed Railway Construction Plan' declaration by China's Ministry of Railways, China's High-speed Railway construction plan officially began from 1997 to 2007, China entered the era of high-speed railways by promoting high-speed railway plans a total of six times.

In 2004, China's mid-to-long-term railway network plan presented a basic railway development plan for China's High-speed Railway development in the form of "four verticals and four horizontals." In response to the 2008 global financial crisis, China decided to include high-speed railway construction in its Gyeonggi stimulus plan for infrastructure development. Due to the impact of the 2008 financial crisis, China has agreed to include high-speed railway construction in its China infrastructure development economic stimulus plan to promote economic growth. A mid-to-long-term railway network plan was established to adjust the passenger high-speed railway route from the existing 12,000 km to 16,000km by 2020.

By the end of 2015, the '4 vertical, 4 horizontal' basic framework for high-speed railway development planned by China was completed. By this time, the total length of China's high-speed railway operation had reached 19,000 km. With this figure, China ranks first in the world, accounting for more than 60% of the total length of high-speed railways in operation worldwide, and has firmly established itself as the world's best high-speed railway country. In 2021, the railway operating distance exceeded 150,000 km, including more than 40,000 km of high-speed railway.

In July 2016, the 'mid-to-long-term railway network plan' was proposed to build an '8 longitudinal, 8 horizontal' high-speed railway network in a new era. The objective was to construct large cities and small and medium-sized cities into a 4-hour transportation zone and urban clusters into a 2-hour commuting zone.

On January 18, 2022, the State Council announced the "14th Five-Year Plan for Development of a Modern Comprehensive Transportation System". The current objective of the High-speed Railway is that cities with a population of more than 500,000 in China will basically fall within the scope of the high-speed railway network by 2025.

China High-speed Railway's operating philosophy is to pursue high speed, efficiency, and safety first. The China High-speed Railway system provides high-speed operation, on-time arrival, and safe and stable service through technology and facilities. Train strives to provide a convenient and stable travel experience by accurately booking and managing passengers so that they can arrive at their destination on time.

The second is networking and connectivity. China's High-speed Railway is committed to building a comprehensive network system connecting all major cities and regions in China. High-speed railway routes are networked so passengers can travel between cities quickly and easily via high-speed railways.

The third is service and experience. China High-speed Railway focuses on providing quality service and good passenger experience. The train is equipped with comfortable seats, dining cars, restrooms, and other facilities, making efforts to provide a comfortable travel environment for passengers. High-speed Railway also provides a convenient ticketing system, self-service facilities, and an online reservation system. Lastly is sustainable development. China High-speed Railway uses advanced technology and equipment to improve energy efficiency and reduce environmental pollution and resource consumption. In addition, developing connected transportation systems reduces dependence on road transportation and improves overall transportation efficiency.

This way, China's High-speed Railway's operating philosophy is to provide customers with fast, efficient, safe, and convenient travel services and is striving for the nation's transportation and economic development through a networked operating model, quality service, and sustainable philosophy.

As a result, the proportion of China's High-speed Railway continues to increase. China's railway total traffic increased from 1,461.93 million in 2008 to 2,203.5 million in 2020. Among these, high-speed railway traffic grew rapidly from 7.34 million in 2008 to 1.557.07 million in 2020. The share of high-speed railway traffic increased significantly from 0.50% in 2008 to 70.66% in 2020.

| Table 6-3 | Status of China's high-speed rail traffic (10,000 people)

	Railway total traffic volume (10,000 people)	High-speed railway transportation capacity (10,000 people	High-speed Railway proportion
2008	146,193	734	0.50%
2009	152,451	4,651	3.05%
2010	167,609	13,323	7.95%
2011	186,226	28,552	15.33%
2012	189,337	38,815	20.50%
2013	210,597	52,962	25.15%
2014	235,704	70,378	29.86%
2015	253,484	96,139	37.93%
2016	281,405	122,128	43.40%
2017	308,379	175,216	56.82%
2018	337,495	205,430	60.87%
2019	366,002	235,833	64.43%
2020	220,350	155,707	70.66%

Source China Statistical Yearbook 2021

Section 5 Comparison and Future of Korea High-speed Railway

1. Comparison

The emergence of high-speed railways has significantly changed the spatial structure of the country due to improvements in travel speed.

Each country maximizes its effects through intensive investment in railway transportation and transportation policies centered on high-speed railways. Due to the efficient use of this high-speed railway, connectivity with or supplementation with existing lines is also an issue. In the case of Korea, the existing lines were initially operated directly connected to the High-speed Railway, and in the case of China, they are used for freight transport and tourist transport. Due to increased users, high-speed railways are developing station complexes and surrounding commercial districts.

In particular, looking at the relationship between economic growth and high-speed railway traffic, in the case of Japan, Shinkansen traffic over the past 50 years had a robust correlation with economic growth. Transportation demand increased with the opening of the Tokyo Olympics in 1964, the Osaka Expo in 1970, and the Sanyo Shinkansen in 1975. In 1964, transportation volume was 11 million people; in 1973, it was 100 million, and transportation demand remained relatively high from 1977 to 1986. The reason is that National Railways was in deficit and needed more capital investment.

After the privatization of National Railways, demand increased due to the introduction of new vehicles. There is a high correlation between economic indicators and Shinkansen traffic volume because there is a high correlation between the population of the Shinkansen passage area and the economic power of the stop station. The background for constructing the linear Shinkansen, scheduled to open in 2027, is to prepare for earthquakes and Shinkansen deterioration. It will drive growth and the growth of passing cities in preparation for the era of population decline, which is expected to decrease to 90 million in the future.

Korea and Japan are also developing based on similar experiences. Meanwhile, the three East Asian countries have different aspects in the development of high-speed railways. Looking at the construction background of High-speed Railway, the factors applied are: Japan is building a new high-speed railway system due to economic growth and saturation of track capacity; in the case of Korea, saturation of existing lines and introduction of a new, future-oriented transportation system; in the case of China, high-speed railway and regional development befitting high economic growth. In terms of growth, Japan has established a new route for balanced regional development with the passage of the Seibi Shinkansen Act, and the development is accelerating recently with linear Shinkansen.

In the case of Korea, along with the high-speed railway new line, the effect is being maximized by recently operating high-speed trains using existing lines. In the case of China, the 8-way, 8-way strategy connects the entire country with a high-speed railway network, connecting not only the main trunk lines but also the western region and international routes.

Among the organizations and laws that promoted high-speed railways, Japan quickly promoted them by establishing a Railway Transport Maintenance Organization. In Korea, this was promoted by establishing the High-speed Rail Construction Corporation. China proceeded with high-speed railway construction led by the Government of Japan Railways. The people who promoted high-speed railways included the efforts of the Sogo Governor and airplane engineers in Japan. In the case of Korea, the driving force of Minister Kim Chang-geun and officials and foreign technology and capital were appropriately utilized.

| Table 6-4 | Comparison of countries related to high-speed railway

Category	Japan	Korea	China
Construction Organization	Railway Construction Corporation(1964)	High-speed Rail Construction Corporation(1992)	China Rrailway Construction Corporation(1990)
High-speed railway-related law	Seibi Shinkansen Act(1970)	High-speed Rail Construction Promotion Act(1997)	Railway Law of the People's Republic of China (1990)
Funding	Government, local governments, operating companies	government support, public bond issuance	government support
Feature	Public and private cooperation type	Government and public cooperation type	Government-led type
Operation	Private Company	Korail, SR	Railway Co., Ltd. (18 regions)
Development	linear Shinkansen (2027 Opening)	Extension of high-speed railway network using existing lines	Extension of the national high-speed railway network; Currently, from 40,000km to 65,000km

The differences between each country based on train stations and developments so far are as follows.

First, there is a difference in policy regarding railways. In Korea, publicness and enterprise are pursued together, while Japan focuses on enterprise, and China has a solid public goods aspect due to its socialist nature. Reflecting this, Japan operates as a JR company, China operates as a government enterprise, and Korea operates as a public enterprise. The ranking of freight rates is Japan>Korea>China, and responsibility for operation is also operated by companies in Japan, public corporations in Korea, and government support in China.

In particular, recent changes in China Railway are noteworthy. It is working to build unblockable and fast transportation rights across the country. The proposed realization goals are as follows: by 2035, '123 transportation rights nationwide' (commuting within 1 hour within a city, 2 hours between cities, and within 3 hours within major cities nationwide); and 'Global 123 high-speed logistics zone' (arrival within China within one day, neighboring countries within two days, and major cities around the world within three days).

Second, there were differences in the development methods of the high-speed railway system and vehicles. Japan has its own development method, and Korea, as a latecomer, has achieved the present by importing and later conducting independent development. In the case of China, it imported technology from advanced countries and developed its own technology based on it. Shinkansen, which began operating in the Tokyo-Shin-Osaka section on October 1, 1964, became the first in the world to operate a high-speed train exceeding 200 km/h and had an impact on railways around the world.

It was highly evaluated in terms of technology and contributed greatly to economic growth through mass transportation with excellent safety and stability. Shinkansen was the result of a long period of review, investigation, and research by Japan's state-owned railway engineers at the time. Among them, it was possible because of the research on high-speed railways hosted by the Railway Technology Institute at Ginza Yamaha Hall in 1957 and the experimental line (Kamomiya-Ayase) from June 1962 to April 1964.

In particular, high-density mass transportation and accurate operation schedules, safety with zero passenger fatalities over 50 years, and an increase in the convenience of the railway contributed significantly to economic growth by contributing to the movement of many people.

Technologically, the Shinkansen was based on alternating current electrification technology, which was the basis for high-speed train operation, and electronic technology for each component. In the vehicle, the optimal frontal linear form minimizes the driving resistance of the vehicle body and lightweight technology; on the track, there was a turnoff device that prevents vibration when passing a long rail at high speed. In operation management, it was equipped with ATC and CTC to ensure safe high-speed driving. This technology was created through the efforts of the National Railways, Railway Technology Institute, vehicle manufacturers, and railway companies.

Third, in the case of the route, in the case of Japan, the main base cities, Tokyo-Nagoya-Osaka, were initially connected and expanded north to south to connect to the north where Fukuoka and Aomori are located. Afterward, due to the Seibi Shinkansen, the high-speed railway was expanded to areas without demand, and the route was expanded to the Kyushu and Hokkaido regions.

In the case of Korea, the Gyeongbu Line and Honam Line were opened using existing lines and were later expanded to include the Suseo High-speed Railway in 2016. In the case of China, the high-speed railway network started in the populous eastern region and then expanded into the inland.

Looking at the differences in the operating methods of the three countries, In Korea, there was the use of existing lines; in the case of Japan, high-speed railways were operated at standard gauge, which was differentiated from the narrow gauge of existing lines; in the case of China, it was being operated in a way that connects the entire country in 8 longitudinal and 8 horizontal directions by expanding routes focusing on high-speed railways.

Fourth, there are differences in overseas expansion strategies. In the case of Japan, high-speed railways were launched in Taiwan and exported to India, etc.

Fifth, there is also a difference in terms of influence. It is also due to the difference in land area, and in the case of Korea, the result can be large due to the relatively small land area. In fact, in the case of Korea, the influence is concentrated around the metropolitan area. In the case of stop stations such as Gwangmyeong, Cheonan-Asan, Daejeon, Daegu, and Busan, the area of influence is 70km, extending over most of the country. In the case of China, the influence is great due to its large population, and in Japan, the effect of high-speed railways is great based on its economic power. In the case of Japan, a high-speed railway discount fare policy was adopted during a period of low economic growth, and there is a support system from Japan's local government to encourage commuting and commuting to school. Japan's High-speed Railway has three strategies. That's 10,000 yen, 4 hours, and 30 days. In the representative route between Tokyo and Osaka, the fare must be less than 10,000 yen one way, it must be possible to travel across the country within 4 hours, and reservations must be possible up to 30 days in advance. In the case of Tokyo~Osaka, the discounted fare for airplanes is less than 10,000 yen, the regular fare for Shinkansen is 13,850 yen, and even with the discount, the regular fare for the railway is 11,230 yen. In terms of time, if you compare the waiting time of an airplane, it is similar to about 3 hours. Therefore, for railways to compete more in fares, fares must be lowered to below 10,000 yen.

Additionally, the 4-hour rule states that competitiveness can be achieved when you can reach anywhere in the country by rail within 4 hours. This is the time to reach the destination, so even if you transfer, the railway can have an advantage over other means of transportation if it has time competitiveness.

In fact, the demand for airplanes is overwhelmingly large between Tokyo and Fukuoka and Osaka and Kagoshima, which are distances of around 1,000 km. In the 800 km Shinkansen 4-hour section between Tokyo and Hiroshima and Nagoya and Fukuoka, the demand for both means of transportation is almost the same. When the distance is shorter than this, the demand for railway transportation is much greater, so the influence of the Shinkansen can be confirmed, and even if connected transportation is used, the railway can have competitiveness within 4 hours.

In the case of Japan, Hokkaido Shinkansen and Hokuriku Shinkansen have recently opened, allowing you to enjoy the beautiful nature of the region and the slow passage of time. Hokuriku Shinkansen can quickly take you to Doyama and Ganazawa and experience the wildlife there. By moving from Tokyo to Doyama to Shinkansen and connecting with the local railway, Doyama Local Railway, you can experience the nature of the Northern Alps Mountains over 3,000 meters high, the local railway station, and the aesthetics of slowness.

2. Implications and Lessons

The emergence of high-speed railways brought about significant changes in the country's territory due to improvements in travel speed.

In addition, each country is maximizing its effects through intensive investment in railway transportation and transportation policies centered on High-speed Railways. With the efficient use of this high-speed railway, connectivity with or supplementation with existing lines is also a task. In the case of Korea, the existing line was initially operated directly with the high-speed railway, and in the case of China, it is used for freight transport and tourist transport. Due to increased users, high-speed railways are developing station complexes and surrounding commercial districts.

In particular, looking at the relationship between economic growth and high-speed railway traffic, in the case of Japan, Shinkansen traffic over the past 50 years had a powerful correlation with economic growth. Transportation demand increased during the 1964 Tokyo Olympics, 1970 Osaka Expo, and 1975 Sanyo Shinkansen opening. In 1964, transportation volume was 11 million people; in 1973, it was 100 million people, and transportation demand remained relatively high from 1977 to 1986. The reason is that National Railways was in deficit, and there was little capital investment.

After the privatization of the National Railway, demand increased due to the introduction of new vehicles. There is a high correlation between economic indicators and Shinkansen traffic volume because there is a high correlation between the population of the Shinkansen passage area and the economic power of the stop station. The construction background of linear Shinkansen, scheduled to open in 2028, is to prepare for earthquakes and Shinkansen deterioration, and it will drive growth and the growth of passing cities in preparation for the era of population decline, which is expected to decrease to 90 million in the future.

Korea and Japan are also developing based on similar experiences. Meanwhile, the three East Asian countries have different aspects in the development of high-speed railways. Looking at the construction background of the high-speed railway, the factors at play are as follows: Japan was building a new High-speed Railway system due to economic growth and saturation of track capacity; Korea was also experiencing saturation of existing lines and introduction of a future-oriented new transportation system; in the case of China, high-speed railway and regional development befitting high economic growth.

In terms of growth, Japan has established a new route for balanced regional development with the passage of the Seibi Shinkansen Act, and the result has recently been accelerating with linear Shinkansen. In the case of Korea, along with the high-speed railway new line, the effect is being maximized by recently operating high-speed trains using existing lines. In the case of China, the 8-way, 8-way strategy connects the entire country with a high-speed railway network, connecting major trunk lines, the western region, and international routes.

The organizations and laws that promoted high-speed railway include: In the case of Japan, the Railway Transport Maintenance Organization was established to promote high-speed railway quickly; in the case of Korea, this was promoted by establishing the High-speed Rail Construction Corporation China proceeded with high-speed railway construction, led by the Government of Japan

Railways. The people who promoted high-speed railways included the efforts of the Sogo Governor and airplane engineers in Japan; in the case of Korea, the driving force of Minister Kim Chang-geun and officials and foreign technology and capital were appropriately utilized.

The differences between each country based on train stations and developments so far are as follows.

First, there are differences in policies regarding railways. In the case of Korea, publicness, and enterprise are pursued together, Japan focuses on enterprise, and China has a solid public goods aspect due to its socialist nature. Reflecting this, Japan operates as a JR company, China operates as a government enterprise, and Korea operates as a public enterprise. The ranking of freight rates is Japan>Korea>China. Corporations in Japan, public corporations in Korea, and national support in China are also responsible for the operation.

In particular, recent changes in China Railway are noteworthy. We are working to build unblockable and fast transportation rights across the country. Our goals are as follows: By 2035, '123 transportation rights nationwide' (commuting within 1 hour within a city, 2 hours between cities, and within 3 hours within major cities nationwide); and 'Global 123 high-speed logistics zone' (arrival within China within one day, neighboring countries within two days, and major cities around the world within three days).

Second, there were differences in the development methods of the high-speed railway system and vehicles. Japan has its development method, and Korea, as a latecomer, has achieved the present by importing and later conducting independent development. In the case of China, it imported technology from advanced countries and developed its technology based on it.

Shinkansen, which began operating on the Tokyo-ShinOsaka section on October 1, 1964, became the first in the world to operate a high-speed train exceeding 200 km/h and had an impact on railways around the world.

It was highly evaluated regarding technology and contributed greatly to economic growth through mass transportation with excellent safety and stability. Shinkansen was the result of a review, investigation, and research by the Japan National Railway technology team over a long period before the war. Among them, it was possible because of the research on high-speed railways hosted by the Railway Technology Institute at Ginza Yamaha Hall in 1957 and the experimental line (Kamomiya-Ayase) from June 1962 to April 1964.

In particular, high-density mass transportation and accurate operation schedules, safety with zero passenger fatalities over 50 years, and an increase in the convenience of railway contributed greatly to economic growth by contributing to the movement of many people.

Technologically, the Shinkansen was based on alternating current electrification technology, which was the basis for high-speed train operation, and electronic technology for each component. In the vehicle, the optimal frontal linear form minimizes the driving resistance of the vehicle body and lightweight technology; on the track, there was a turnoff device that prevents vibration when passing a long rail at high speed. In operation management, it was equipped with ATC and CTC to ensure safe high-speed driving. This technology was created through the efforts of the National Railways, Railway Technology Institute, vehicle manufacturers, and railway companies.

Third, in the case of the route, in the case of Japan, the main base cities, Tokyo-Nagoya-Osaka, were initially connected, and this was expanded north-south to connect to the north where Fukuoka and Aomori are located. Afterward, due to the Seibi Shinkansen, the high-speed railway was expanded to areas without demand, and the route was expanded to the Kyushu and Hokkaido regions. In the case of Korea, the Gyeongbu Line and Honam Line were opened using existing lines and later expanded to the Suseo High-speed Railway in 2016. In the case of China, the high-speed railway network started in the populous eastern region and then expanded into the inland.

Looking at the differences in the operating methods of the three countries, In Korea, there was the use of existing lines; in the case of Japan, high-speed railways were operated at standard gauge, which was differentiated from the narrow gauge of existing lines. In the case of China, it was being operated in a way that connects the entire country in 8 longitudinal and 8 horizontal directions by expanding routes focusing on high-speed railways.

Fourth, there are differences in overseas expansion strategies. In the case of Japan, high-speed railways were launched in Taiwan and exported to India, etc.

Fifth, there is also a difference in terms of influence. It is also due to the difference in land area, and in the case of Korea, the result can be said to be large due to the relatively small land area. In fact, in the case of Korea, the influence is concentrated around the metropolitan area. In the case of stop stations such as Gwangmyeong, Cheonan-Asan, Daejeon, Daegu, and Busan, the area of influence is 70km, extending over most of the country. In the case of China, the influence is great due to its large population, and in Japan, the effect of high-speed railways is great based on its economic power. In the case of Japan, a high-speed railway discount fare policy was adopted during a period of low economic growth, and there is a support system from Japan's local government to encourage commuting and commuting to school. Japan’s High-speed Railway has three strategies. That's 10,000 yen, 4 hours, and 30 days. In the representative route between Tokyo and Osaka, the fare must be less than 10,000 yen one way, it must be possible to travel across the country within 4 hours, and reservations must be possible up to 30 days in advance. In the case of Tokyo～Osaka, the discounted fare for airplanes is less than 10,000 yen, the regular fare for Shinkansen is 13,850 yen, and even with the discount, the regular fare for the railway is 11,230 yen. In terms of time, if you compare the waiting time of an airplane, it is similar to about 3 hours. Therefore, for railways to compete more in fares, fares must be lowered to below 10,000 yen.

Additionally, the 4-hour rule states that competitiveness can be achieved when you can reach anywhere in the country by rail within 4 hours. This is the time to reach the destination, so even if you transfer, the railway can have an advantage over other means of transportation if it has time competitiveness.

In fact, the demand for airplanes is overwhelmingly large between Tokyo and Fukuoka and Osaka and Kagoshima, which are distances of around 1,000 km. In the 800 km Shinkansen 4-hour section between Tokyo and Hiroshima and Nagoya and Fukuoka, the demand for both means of transportation is almost the same. When the distance is shorter than this, the demand for railway transportation is much greater, so the influence of the Shinkansen can be confirmed, and even if connected transportation is used, the railway can have competitiveness within 4 hours.

In the case of Japan, Hokkaido Shinkansen and Hokuriku Shinkansen have recently opened, allowing you to enjoy the beautiful nature of the region and the slow passage of time. Hokuriku Shinkansen can quickly take you to Doyama and Ganazawa and experience the nature there.

3. Future

(1) Carbon Neutrality & Railway

The cause of the recent abnormal climate is due to excessive carbon emissions. The situation in our country is serious. According to data from the Global Carbon Project and the Netherlands Environmental Assessment Agency (PBL) used in the analysis by Korea's Institute for Climate Change Action, Korea's per capita carbon dioxide emissions in 2019 were 11.93 tons. Among the 10 developed countries, it is the third largest amount after the USA (16.06 tons) and Canada (15.41 tons). This was followed by Japan (8.72 tons) and Germany (8.4 tons). If things continue this way, there is a forecast that Korea will rank first in per capita emissions by 2030. Recognizing the seriousness of this problem, Korea enacted the carbon neutrality/Basic Act on Green Growth in 2021. The objective was to reduce national greenhouse gas emissions by more than 35% by 2030 compared to 2018.

Experts analyze that the transportation sector greatly impacts these global excessive carbon emissions. According to the European Environment Agency (EEA), carbon emissions per kilometer are 68g for buses, 55g for passenger cars, and 14g for trains, while airplanes emit the most carbon at 285g. A railway is 1/20th of an aircraft. Developed countries are seriously aware of this and are introducing new measures. The EU has set a 2030 objective of reducing carbon dioxide emissions by 55% compared to 1990 under the European Climate Act. The UK was the first to enact the Climate Change Act in 2019. The USA's main carbon neutrality response strategies are energy efficiency, decarbonization of the power sector, fuel conversion in the transportation and industrial sectors, reduction of non-carbon emissions, and carbon absorption technology development.

France has introduced more concrete measures. In May 2023, '2021 France's Climate Law' officially came into effect two years after it passed the National Assembly. In May 2021, the French Parliament decided to ban short-distance domestic flights with a flight time of less than 2 hours and 30 minutes if there is an alternative railway route to solve the climate change problem. Accordingly, from this day, passenger routes connecting France Paris - Nantes (approximately 350 km), Paris -

Lyon (approximately 390 km), and Paris - Bordeaux (approximately 500 km) will be suspended. This law was promoted to reduce airplane operations, which emit the most carbon emissions among various transportation methods. The climate law that went into effect today also stipulates that trains will be operated frequently and at appropriate intervals on routes where passenger aircraft operations are suspended to avoid inconvenience to travelers. They are also demanding that travelers be able to stay at their destination for eight hours, do some work, and then return to their departure point in one day. Initially, the 'French Citizens' Convention on Climate' (FCCC), a discussion body created by President Emmanuel Macron in 2019, recommended banning passenger aircraft operations on routes where train travel is possible within 4 hours.

If France's measures are applied to Korea, most domestic passenger flights fall into this category, except for routes from Seoul and Busan to Jeju Island. For Korea to realize carbon neutrality, the government stipulates in Article 32, Paragraph 5 of the Carbon Framework Act to continuously expand investment in railways so that railways become the basis of the national transportation network and expand public transportation means such as buses, subway, and light rail, and set and manage mid- to long-term and stage-specific objectives for railway transport sharing ratio, public transport sharing ratio, etc. Based on this, Korea National Railway has recently been actively proposing a railway share ratio to reduce carbon emissions and reduce social costs. The analysis showed that the transport share should be 35% in 2030 and 40% in 2050 for passenger transport, 15% in 2030, and 17% in 2050 for freight transport. The role of railways must be dramatically increased, and to achieve this, regional rail transportation must be integrated, expedited, linked, and automated. In the case of regional railways, high-speed, priority, base, and connection should be promoted. As a promotion strategy, the short term is to operate an intelligent urban express railway, build a mobility station transfer platform, and develop a three-dimensional base centered on the railway station; in the mid-term, digital-based railway operation automation, national rail transportation trunk and branch network construction; in the long term, it is a future Ultra-High-speed Railway service innovation.

(2) Activation of Railway Logistics

Railway logistics forms one axis of passenger and cargo transportation in Korea, and during high-speed railway construction in Korea, the country's overall logistics costs and socio-economic costs were reduced by operating existing lines with a focus on railway freight, hence groundbreaking development was expected as one of the axes driving the development of Korea's railways. Twenty years after the opening of the high-speed railway, we would like to review it again and propose its realization.

If we classify Korea's railway development by the period after liberation, from 1945 to 1960, Korea, which had been devastated after the Korean War, was restored, centered on the railway, and railway transportation gradually recovered. Until 1961, passenger and freight transport volume increased.

The growth of railways marked the period from 1961 to 1980 and then a period of recession. Although transportation volume increased from 1961, the share ratio began to decline due to the growth of road transportation.

In the case of passenger transportation, the passenger share decreased from 8.4% to 4.6% in 1966 on a per-person basis and from 42.5% in 1966 to 32.3% in 1970 on a person·km basis.

During this period, transportation volume stagnated due to decreased investment in railways and stagnation of infrastructure, and railway transport decreased further compared to road transport. In 1980, the share ratio for passengers on a per person basis showed a further decreasing trend, decreasing to 4.2% in 1988 and 21.2% per person·km.

Afterward, the period from 1989 to 2018 was the railway renaissance period, showing a slight recovery after 1989 and maintaining the same level after the opening of the High-speed Railway. The share of railway transport is gradually increasing. However, since 2011, private cars have been added to the statistics, and the railway transport share ratio has decreased further. Passenger traffic volume recovered to 8.0% on a person basis in 2007 and recorded 20.2% in 2005 on a person·km basis.

Meanwhile, looking at the trend of railway freight transport volume, In the case of the restoration and recovery period of the railway from 1945 to 1960, It increased from 631 million tons·km based on 3,045 thousand tons and ton·km in 1946 to 14,423 million tons and 3,283 million tons·km per year in 1960.

During this period, transportation volume temporarily decreased due to the Korean War, but the Hambaek Line was opened in the post-war recovery period.

From 1961 to 1980, the growth of railways and the subsequent recession increased to 15,393 million tons and 3,486 million tons·km in 1961. It temporarily decreased in the early 1970s due to the Oil Shock, etc. Then it increased and decreased repeatedly, reaching its highest point in 1991 and then beginning to show a continuous downward trend.

The transportation volume in 2015 decreased to the 1973 level in terms of tons. The highest point was in 1991 and has been decreasing since then. In the case of the railway renaissance period from 1989 to 2018, there was a temporary decline due to the Lehman shock in 2009. Freight transportation via railway continues to decline due to its inferiority in terms of time and price competitiveness compared to roads.

Looking at the share of freight transport, in terms of tons, in 1966, railways accounted for 47.3% and air routes accounted for 48.2%, which was similar. Afterward, the share of railway transportation decreased to 28.9% in 1976, 18.7% in 1989, 9.7% in 1995, and 1.6% in 2015.

On a ton·km basis, railway freight decreased by 81.5% in 1966, 49.5% in 1976, 37.8% in 1986, 16.5% in 1996, 7.0% in 2011, and 4.5% in 2017.

Meanwhile, freight transport volume continues to decline. In particular, there has been a further decline since 2009. It decreased 30% from 45,240,000 tons in 2000 to 31,670,000 tons in 2017.

In particular, there has been a further decline since 2009. This is because railway transport is less competitive in terms of time and distance compared to road transport. This is because the railway freight transport volume has further decreased due to a lack of investment in railway logistics facilities and benefits such as oil subsidies and highway toll discounts for road transport.

In the case of freight rates, railway freight from Incheon to Busan is competitive compared to road fares at 2,000 to 20,000 won for 20 feet, but when it comes to trucks, railway freight is by no means superior. In the case of 40 feet, it is expensive at 7,000 to 14,000 won, so it is not competitive compared to roads. However, excluding government support factors such as fuel subsidies and Expressway toll discounts, railway freight competitiveness is actually relatively high for long distances.

Compared with overseas countries, the ton·km share of Korea's railway freight was 4.5% in 2017, which is very low compared to 35% in the USA, 23% in Germany, 15% in France, and 12% in the UK.

Looking at the increase in passenger traffic volume and decrease in freight transport volume after the opening of the high-speed railway, through the opening of the high-speed railway, the policy direction was promoted to grow both passenger and freight transport by transporting passenger traffic mainly on high-speed railways and freight transport mainly on existing lines. Due to the lack of effective investment in the freight sector, it can be said that there is some distance from reality.

We want to discuss why railway freight transport needs to grow to some extent. First, railway freight transportation is very efficient and suitable for long-distance transportation. Looking at the 2015 railway statistics, the average travel distance of 1 ton is 262.8km, which means that it is transported over a much longer distance than by car, which means that social costs such as traffic jams and energy savings can be reduced.

Second, it must be suitable for and maintained for the transportation of dangerous goods, waste, weight cargo, and other items that have limitations in automobile transportation.

Third, in preparation for the unification of North and South Korea, railway freight transportation must play a central role in continental logistics in the long term. Starting from Busan, connecting North Korea, Russia, and Europe directly through the Donghae Line is possible. China and the continent can connect directly through the Gyeongeui Line through the Seohaean Line.

Therefore, priority should be given to existing freight transport, and more efforts should be made on cost reduction and mass transport, which are the competitiveness of railway freight, such as high-speed freight trains, longer freight trains, speed improvement, and improvement of adequate logistics facilities. The reasons why railway logistics projects have become more complex than at the time of the Korean National Railroad are as follows. There needs to be more investment in railway logistics facilities. At the time of the Korean National Railroad, facility improvement was carried out through logistics station facility improvement within the range of KRW 5 billion per year. After construction, the budget has disappeared, making even minimal facility improvements difficult. If an existing line improvement project is carried out, the existing railway logistics facilities must also be included in the transfer target. In reality, due to local government avoidance, there are cases where railway logistics are closed on routes where existing facilities are being improved, leading to worsening railway logistics. When the private sector invests in railway logistics facilities, especially warehouse facilities etc., tax reduction provisions for railway logistics facilities that were applied in the past disappear, resulting in a further decline in railway logistics.

In addition, in the case of railway logistics projects, the project portfolio strategy is quite limited, and this is why those promoting railway projects require project diversification to secure future competitiveness through service expansion and profitability creation. In order to resolve project sluggishness and accumulated deficit, like railway operators in advanced railway countries such as Japan and Germany, we need to break away from the typical business methods of passenger and freight transport and provide opportunities for profit creation in the 21^{st} century through diversification of business into various forms. This also acts as a provision that restricts business diversification by being confined within the current enforcement ordinance of the Korea Railroad Corporation Act, which states that only business related to railways is possible; therefore, government-level policy support is needed to revise related provisions to promote project diversification of the railway logistics sector in various ways.

In the future, the government should establish and implement a policy objective to enable railway freight transport at more than twice the current share, considering the socio-economic value of railway freight transport in Korea. To achieve this, the transport subsidy and fuel subsidy systems for multimodal transportation, which are widely used overseas, must be reformed for the establishment of a fuel subsidy support system for shuttle vehicles for railway and road complex transportation, significant reduction of freight track usage fee, investment in railway freight support infrastructure, and comprehensive policies should be pursued, such as expanding support for improvement costs, reviving the logistics facility discount system, and regulating the operation of heavy trucks. Policies that enable the growth of railway logistics projects are needed.

In addition, the possibility of utilizing railway freight vehicles following the extension of the high-speed railway line should be reviewed. Through this, transportation of delivery volume will also be possible.

(3) Future Railway Route & Suggestion

The high-speed railway opened in 2004 and will celebrate its 20th anniversary next year. With the opening of the high-speed railway, the area developed around the stop station along with the rapid movement of passengers. Nevertheless, we have many projects and it is a time when we need a development-oriented perspective to solve them.

First, the Korean railway needs a more international perspective beyond the domestic one, and environmentally, Northeast Asia is changing rapidly, including the development of the China high-speed railway. It can be said that the development of the railway industry is also important for realizing a Carbon Zero society.

Now, in order to survive the fierce competition on the international stage and develop into a major industry to increase national power, innovative thinking that breaks away from the existing framework is actively requested.

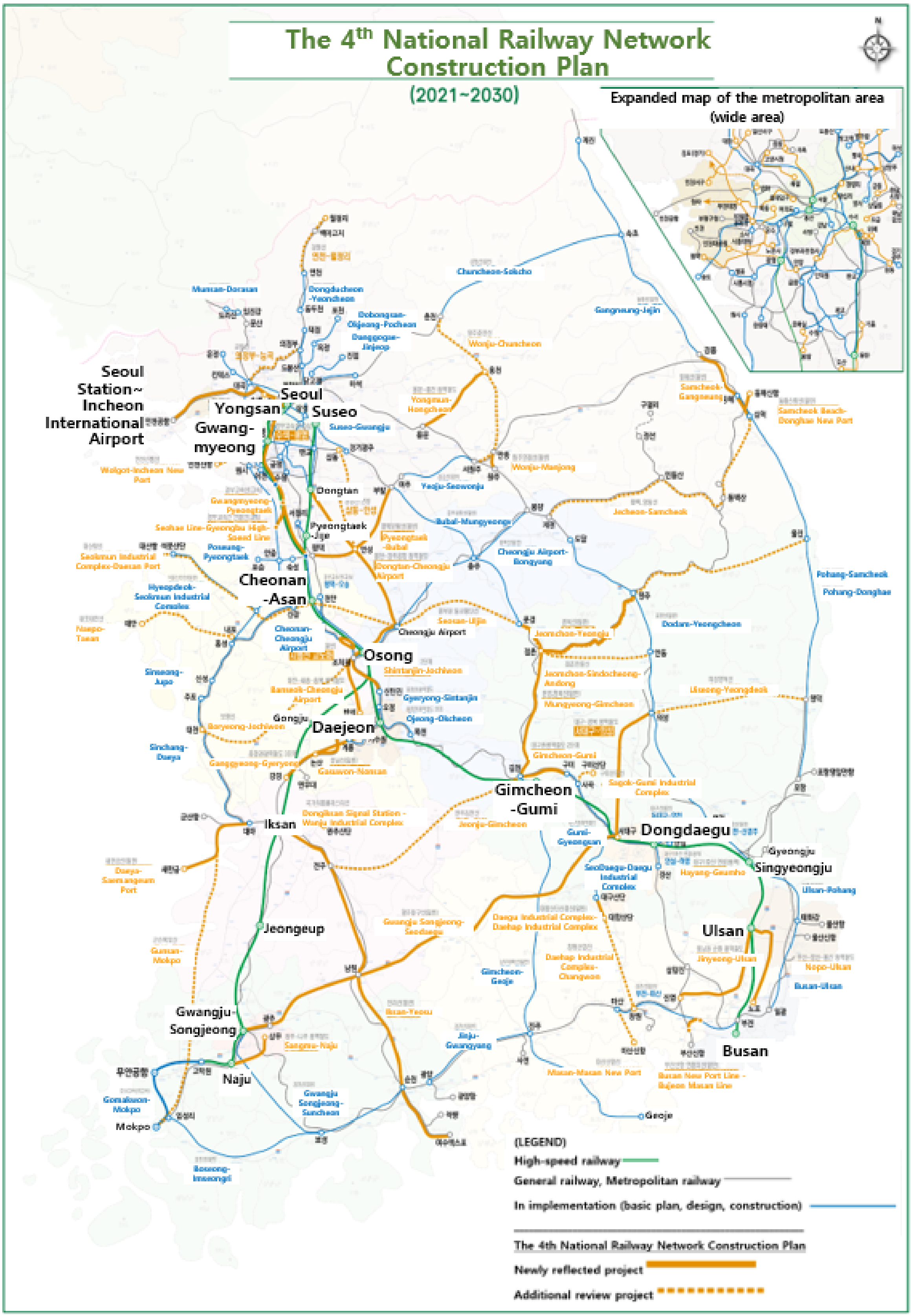
In the future, the government should establish and implement a policy objective to enable railway freight transport at more than twice the current share, considering the socio-economic value of railway freight transport in Korea. To achieve this, the transport subsidy and fuel subsidy systems for multimodal transportation, which are widely used overseas, must be reformed for the establishment of a fuel subsidy support system for shuttle vehicles for railway and road complex transportation, significant reduction of freight track usage fee, investment in railway freight support infrastructure, and comprehensive policies should be pursued, such as expanding support for improvement costs, reviving the logistics facility discount system, and regulating the operation of heavy trucks. Policies that enable the growth of railway logistics projects are needed.

Second, efforts are made to improve the entire domestic network's efficiency and establish future plans. Current tasks include improving the high-speed railway line of the existing line between Seoul and Siheung, the metropolitan area detour route, and efforts to revitalize the existing line. According to the 4th national railway network plan from 2021 to 2030, a total of 44 routes of 1,448.4km in Korea's railway routes are scheduled to be expanded. For high-speed railway lines, Gyeongbu high-speed railway line (Susaek-Gwangmyeong double track train, Gwangmyeong-Pyeongtaek double track Electrification) will be promoted by connecting high-speed railways with existing railways, the future extension of Korea's railway service kilometers will increase by 125% from 4,274km in 2019 to 5,341km in 2030. During this period, 92.1 trillion won will be invested in railways. Through this, the economic impact is expected to be 255.2533 trillion won, and the employment inducement effect is expected to be 469,961 people, which is expected to contribute to Korea's industry development significantly.

| Table 6-5 | Korea Railway Future Project

	Route Name	Project Section	Project Details	Extension (km)	Total Budget (100 million won)
① Operational Efficiency-Improving Project					
High-speed	Gyeongbu high-speed railway line	Susaek~Seoul~Gwangmyeong	Electrified double track	26.6	22,285
		Gwangmyeong~Pyeongtaek	2 double track train	66.3	56,942
General	Mungyeong·Jeomchon Line	Mungyeong~Jeomchon~Gimcheon	Electrified single track	70.7	11,437
	Gyeongbuk Line	Jeomchon~Yeongju	Electrified single track	55.2	2,709
	Airport Railroad	Seoul Station~Incheon International Airport	Express track	63.9	4,912
Metropolitan	Bundang Line	Wangsimni~Cheongnyangni	Electrified single track	1.0	820
Subtotal (6 Projects)				283.7	99,105
② high-speed railway connection project between major bases					
High-speed	Seohae Line~Gyeongbu high-speed railway line connection line	Hwaseong Hyangnam~Gyeongbu high-speed railway line	Electrified double track (direct connection)	7.1	5,491
General	Gwangju~Daegu	Gwangju Songjeong~서Daegu	Electrified single track	198.8	45,158
	PyeongtaekBubal Line	Pyeongtaek~Bubal	Electrified single track	62.2	22,383
	Wonju Connection Line	Wonju~Manjong	Electrified double track (direct connection	6.6	6,371
	Donghae Line	Samcheok~Gangneung	Electrified single track (semi-High-speed)	43.0	12,744
	Jeolla Line	Iksan~Yeosu	Electrified double track (semi-High-speed	89.2	30,357
	Honam Line	Gasuwon~Nonsan	Electrified double track (semi-High-speed)	17.8	7,415
Subtotal (7 Projects)				424.7	129,919
③ Non-Metropolitan area Metropolitan Railway Extension Project					
Subtotal (11 Projects)				444.3	121,074
④ Metropolitan area traffic congestion Relief Project					
Subtotal (15 Projects)				229.4	216,405
⑤ industry development Infrastructure construction project Project					
Subtotal (5 Projects)				66.3	21,094
Total (44 Projects)				1,448.4	587,597

Source Ministry of Land, Infrastructure and Transport 4th National Railway Network Confirmation Project



| Figure 6-1 | Korea's future railway network (The 4th National Railway Network Plan 2021-2030)

Source The 4th National Railway Network Construction Plan

Europe's recent transportation policy maximizes its effectiveness by connecting all major airports and ports by railway. In addition, in preparation for population decline, this must be overcome through station influence area development and TOD method development.

What is requested is the preparation of a master plan that can include several projects such as: the Korean railway future blueprint, route network and new high-speed dedicated lines, improved facial speed, various operation methods, location of maintenance depots, and train station development. method, vehicle development plan, overseas certification efforts for parts, groundbreaking service improvement, and overseas expansion.

Third, active development of new technology is needed. Railway technology can be said to be the engine that leads the system and a comprehensive knowledge system, and we experience safe movement and convenience at every moment through smart mobility.

High-speed railway technology development is ongoing, and Japan recently plans to open the maglev train in 2027. In the case of China, according to a recent announcement, the maglev train recorded a maximum speed of 623 km/h in non-vacuum conditions. It was announced that in the future, a hyperloop train with a speed of 1,000 km per hour will be considered in the 150 km section between Shanghai and Hangzhou. We will need to continue to pursue the development of components with international patents along with the development of next-generation high-speed vehicles. The recent push for the development of hyperloop vehicles can be said to be valuable as future preemptive research.

In order to commercialize railway R&D technology, orderers must be able to make purchases in a freer environment. If you purchase a new technology-developed product, efforts are required to provide incentives, revitalize purchase conditional research, protect and foster development technology in Korea, and expand the scope of performance recognition at the time of purchase. Changes in reverse engineering through changes in design standards and the introduction of various vehicles should also be promoted.

To build a foundation for fostering the railway industry, in order to create a stable domestic market foundation and strengthen support for small and medium-sized businesses, support for core component development, modularization, and standardization is needed.

Currently, it is difficult for private companies to develop core technology that requires development due to profitability, so basic technology must be developed to some extent in a government-led manner. To this end, it is necessary to strengthen railway cooperation, activate decision-maker and researcher meetings, and focus on participation in the construction sector, operation sector, and O&M sector, where Korea has strengths in overseas expansion.

With the independence of railway technology and the improvement of international capabilities, the competitiveness of the railway industry will become a new growth engine driving the economy. To this end, cooperation between the government, companies, research institutes, and universities is needed more than ever.

The fourth is the development of the railway industry and overseas expansion. The railway, which is used by 13.5 million people, or about 26% of the population, every day, is safe and convenient. As an important lifeline of society with a public nature for realizing a Carbon Zero society, its value and influence are gradually increasing. The railway industry, which leads this, has the task of establishing itself as a key domestic industry and increasing competitiveness, including increasing exports.

High-speed railways have made it possible to travel between major cities across the country within two hours, greatly changing life, the economy, and thinking. The revolution in mobility technology brought about by the railway during the Industrial Revolution was in full bloom in the 20th century. The global railroad market is worth 240 trillion won (as of 2020). Korea is the fourth country in the world to succeed in producing high-speed railway vehicles and it will need to advance overseas based on these capabilities.

Our railway must compete with China's BRI (Belt and Road Initiative), which is recognized by others as the strongest railway country, and Russia's 'New Eastern Policy (NEP)', which operates the Trans-Siberian Railway (TSR), the world's longest route. It is literally a state of war. In order to survive the fierce competition on the international stage and develop into a major industry to enhance national power, new thinking that breaks away from the existing framework is actively requested.

However, the domestic and international projects we currently have to solve are not easy. In Korea, the number of railway vehicles ordered domestically over the past six years is approximately 530 units per year, valued at approximately KRW 514 billion. It only accounts for about 40% of the annual production capacity of completed railway vehicles, and even for this, the three companies are competing. R&D in the railway sector has been stagnant since 2013. There is a gap of about five years in railway technology compared to Japan, France, and Germany, which are at the highest level at 80% of developed countries.

Moreover, even products that have been developed with technology are not commercialized in many parts of the country. Due to international competitiveness, such as dependence on imports for core parts, its share in the global railroad market remains at around 2%. There have been various discussions and proposals for development regarding railway technology, but the reason for the slow progress can be attributed to the lack of deep recognition at home and abroad of the value and importance of railways.

Overseas, the railway industry is classified as a national key industry that is directly related to the safety of the people, and every effort is made to protect the domestic industry and foster domestic companies.

China, which is a relative latecomer in railway terms, is focusing on strengthening the overseas competitiveness of companies based on domestic demand, unlike Korea, which encourages competition among domestic companies.

In Europe, joint ventures between countries are also being promoted to respond to China's low-price offensive. Alstom, a French railway vehicle manufacturer, acquired and merged the Canadian Bombardier railway project sector. With the merger, another giant dinosaur was created following China, and the position of the Korean railway industry in overseas markets, which has a weak domestic demand base, is not favorable.

In order for us to leap forward as an advanced railway, the development of technology and the railway industry are key, but we need several new alternatives. In order to strengthen competitiveness in overseas expansion, it is necessary to go beyond simple supervision and engineering and foster international private companies to improve the ability to receive large-scale overseas orders, active support from the government, and expansion and globalization of parts companies. For example, a late differentiation strategy is needed for overseas expansion. This is a strategy in which each company jointly produces 80% of export products in sectors with economies of scale and differentiates only the remaining 20% by region. By doing this, costs will be reduced, and products that overseas customers want can be produced. The operations and maintenance sector also broke away from the system that had so far relied on public enterprise operations. We need to secure competitiveness through various exchanges with the private sector and lay the foundation for participating in overseas railway operation project bidding.

Our railway must compete with China's BRI (Belt and Road Initiative), which is recognized by others as the strongest railway country, and Russia's 'New Eastern Policy (NEP)', which operates the Trans-Siberian Railway (TSR), the world's longest route. It is literally a state of war. In order to survive the fierce competition on the international stage and develop into a major industry to enhance national power, new thinking that breaks away from the existing framework is actively requested.

Lastly, as a suggestion, I would like to establish a plan to build a state-run railway museum to commemorate 20 years of high-speed railway in Korea. Japan also approved and announced a construction plan for the next-generation high-speed railway, Linear Shinkansen, for the 50th anniversary of the Shinkansen in 2015, along with a plan to build various museums to commemorate the opening of the high-speed railway in 1964.

Now we must look ahead to the next 50 or 100 years and begin discussions on building a national railway museum. In particular, there is a need to include the development process and contents of the high-speed railway, so the construction of a future-oriented museum will be the key.

20-year History of Korean High-speed Rail

1973 Dec.73. - Jun.74.
- At the request of the World Bank in relation to the introduction of railway loans, The French national railway investigation team and the Japan Overseas Railway Technology Cooperation Association proposed the construction of a new railway on the Gyeongbu axis as a long-term measure.

1978 Nov.78. - Jul.81.
- Korea Institute of Science and Technology (KIST): "Research on improvement of bulk cargo transportation system and optimization of transportation investment" (Ministry of Transportation) - Proposed to prioritize the construction of a railway network and the construction of a new railway on the Gyeongbu axis.

1981 Jun.81.
- '86-89 Seoul-Daejeon (160㎞) High-speed Rail Plan: Reflected in the 5th Five-Year Economic Development Plan ('82-'86)

1983 Mar.83.
- When revising the 5th Five-Year Economic and Social Development Plan, it has been revised to decide whether to construct the Gyeongbu High-Speed Railway after conducting a feasibility study;

Mar.83. - Nov.84.
I- Implementation of feasibility study on long-term transportation investment and high-speed rail construction on the Seoul-Gyeongbu axis;
(Ministry of Transportation) - Lewis Berger of the U.S., Camp Sachs of Denmark, Korea Research Institute for Human Settlements, Hyundai Engineering
- As the railway and highway along the Gyeongbu axis reached their limit by the early 1990s, the need for expansion of new transportation facilities was suggested.
- In the long term, railway-centered alternatives are more economically feasible and high-speed rail construction is advantageous.

1986 Sep.86.
- The decision to conduct a technical survey on the Gyeongbu High-Speed Rail was reflected in the 6th Five-Year Economic and Social Development Plan ('87-'91).

1989 8.May.89.
Decision on Gyeongbu High-Speed Rail Construction Promotion Policy:
- SSeoul-Busan (approximately 380km) Double Track New-Line Construction;
- Driving speed: over 200 km/h on average;
- Construction period: '91.8.~'98.8. (7 years);
- Required funds: 3.5 trillion won (national treasury support)

24.Jul.89.
High-speed rail and new international airport construction promotion committee launched:
- Chairperson: Deputy Prime Minister and Minister of Economic Planning Board
- Vice Chairman: Minister of Transportations

Jul.89. - Feb.91.
Implementation of technical survey for Gyeongbu High-Speed Railway (Railroad Administration):
- Transportation Development Research Institute: Economic analysis and service management;
- Yushin Design Corporation, Railway Technology Cooperation Association: Route, civil engineering survey;
- Hyundai Precision Industries, Daewoo Heavy Industries: Research on vehicle-related technologies;
- Louis Berger: Overall technical investigation, including system analysis, train operation, vehicle structure, dynamics, and control, power system, and civil engineering.

16.Oct.89. - 22.Oct.89.
High-speed rail international symposium held:
- Attendance: 631 people (100 people from 10 foreign countries, including Japan, France, Germany, and the United States)

1.Dec.89.
Establishment of a high-speed rail planning office at the National Railroad Administration:
- 54 people (Railroad Administration employees), including the director (level 2) and 5 managers (level 4)

1990 15.Jun.90.
Gyeongbu high-speed rail route decided:
- Section: 409km between Seoul and Busan
- Designed maximum speed: 350 km/h
- Construction period: '91.8.~'98.8. (7 years)
- Required funds: KRW 5.8462 trillion
- Installation of intermediate stations: 4 stations (Cheonan, Daejeon, Daegu, Gyeongju)
- High-speed train method: rail adhesion type (wheel train)

1991 18.Feb.91.
Expanded and reorganized the High-Speed Rail Planning Department into the High-Speed Rail Project Planning Group:
- Director General (political service), Vice-Director General (level 1), 5 countries (level 2-3)
- Personnel: 140 people (public officials from 10 government ministries and financial sector employees dispatched to work);
May.91.- Apr.92.
Aerial photogrammetry for the optimal route (200m width on each side);
3.Jun.91.
Commencement of roadbed detailed design service between Seoul and Busan;
3.Jun.91.
Send request for proposal (RFP) to select vehicle type:
- Target countries: Japan, France, Germany (Deadline: January 31, 1992)

1992 9.Mar.92.
『Korea High-Speed Rail Construction Corporation』 launched:
- Organization: Chairman, auditor, vice-chairman (2 people), 7 headquarters, 10 offices, 17 bureaus (Total 379 people)
- Function: Domestic and international high-speed rail construction, research, development, and survey of high-speed rail technology, development projects in areas near high-speed rail stations and along high-speed rail lines, etc.
※ The Korea Railroad Administration's High-Speed Rail Project Planning Group was abolished.
10.Jun.92.
High-speed rail detailed route confirmed (7th Promotion Committee on April 30, 1992):
- List of departure/terminal stations and administrative districts passing through the route (Eup, Myeon, Dong level)
30.Jun.92.
Start of construction of 4 sections of test line section (Cheonan ~ Daejeon):
- The roadbed was constructed using domestic technology, and construction began before the vehicle model is decided to achieve the `98 completion goal (Groundbreaking ceremony at 10:30, Cheonan Station site)

1993 14.Jun.93.
High-speed rail construction plan revised (9th Promotion Committee):
- Project cost: KRW 5.8462 trillion (`89 price) → KRW 10.74 trillion (`93 price)
- Construction period: `92~`98 → 2001 (Seoul-Daejeon, `99)
- Financing: 45% financial support, 55% self-funding
- Modification of business details
· Daejeon/Daejeon Station installed on the ground; bridge deck restructured to PC BEAM
· Anyang-Seoul Station-Susaek underground line plan was revised to utilize existing lines;
20.Aug.93.
- Selected the preferred negotiating party for vehicle negotiations (Alstom, France)

1994 20.Jan.94.
- Abolition of Railway Technology Research Institute; Establishment of Railway Technology Research Institute;
14.Jun.94.
- High-speed rail supply contract signed between Korea High-Speed Railroad Authority and Korea TGV Consortium; Vehicle introduction contract concluded (negotiation results announced on April 18):
- The orderer is the High Speed Rail Construction Corporation, and the supplier is the Korea TGV Consortium.
- Contract amount: Approximately 2.1 billion dollars (approximately 3.7 billion dollars was initially proposed)
12.Aug.94.
Signed a contract to introduce $2.337 billion in public loans:
- Deputy Minister: 25 financial institutions, including Bank Endo Suez (7 domestic, 18 overseas)

1995 25.Apr.95.
Daejeon-Daegu section: Underground route plan revised (14th Promotion Committee)

1995 - Local residents were concerned about environmental damage such as urban nourishment during above-ground construction and noise and vibration caused by train operation, so they requested modification of the underground route.
July.95.
Ministry of Science and Technology G7 Phase 2 New Candidate Project Contest Announcement

1996 20.Mar.96.
- Launch of Railway Technology Research Institute;
Apr.96.
Selected as a G7 project by the "Leading Technology Development Project Council";

1996 5.Jun.96.

In order to protect cultural assets, a decision was made to select and promote a new route for the 68km section of the Gyeongju route (15th Promotion Committee):

- Between Daegu and Busan, the existing Gyeongbu Line is to be electrified and high-speed rail is planned to operate normally across the entire Seoul-Busan section in 2002.

1.Aug.96.

Safety diagnosis of pre-construction structures conducted by WJE, USA:

- Period: `96.8.1. ~ `97.1.31.
- Inspection target: Structures constructed from the start of construction in `92.6 to `96.4.26.
- Safety diagnosis cost: $2.83 million (approximately KRW 2.4 billion)

23.Nov.96.

『High-Speed Rail Construction Planning Group』 established in the Ministry of Construction and Transportation:

- A total of 22 people, including 2 Director General (level 2-3) and managers (level 4) (expansion and reorganization of the high-speed rail department)

31.Dec.96.

- Enactment and Promulgation of the High-Speed Rail Construction Promotion Act (Enforcement took place in next March)

Dec.96.

- Research institute contest, selection and 1st year agreement, research commencement;

Start of high-speed rail development project (until October 2002)

1997 25.Jan.97.

- Gyeongju section route: Hwacheon-ri route decided (16th Promotion Committee);

24.Feb.97.

- Change of route for the abandoned mine passage section of the Shanghai Tunnel (Section 2-1);

14.Apr.97.

- Announcement of safety inspection results by US company WJE;

Jul.97.

- Start of technology transfer;

8.Sep.97.

- Announcement of business plan changes (draft) and holding of public hearings, etc.;

14.Nov.97.

Discussing basic plan changes (draft) with 24 related organizations:

- Project cost: KRW 10.74 trillion → KRW 17.5028 trillion
- Project period: 2002.5. → 2005.11.
- Analysis: B/C 1.55 → 1.22, IRR 19.4 → 1.22
- Performance: 7 years → 11 years after opening of profit conversion, 17 years → 29 years after opening of debt repayment

※ The promotion of basic plan changes is postponed due to worsening economic conditions such as the IMF.

1998 23.Jan.98.

『High-Speed Rail Construction Deliberation Committee』 formed and the 1st meeting held:

- Function: Mainly deliberation on specialized technical fields (Article 9 of the High-Speed Rail Construction Promotion Act);
- Committee members: 8 from central ministries, 14 from local governments, 20 from the civil engineering field, 12 from the railroad, transportation, and urban fields, 17 from the architectural field, and 10 from other fields.

3.Apr.98.

Decision on business plan change review policy:

- To review the project cost and project period, an evaluation advisory committee consisting of a joint working group of related organizations, a private business feasibility analysis team, and experts from various fields was formed and promoted.

8.Jul.98.

Discussing basic plan changes (draft) with 24 related organizations

31.Jul.98.

Decision to change the high-speed rail basic plan (19th Promotion Committee):

- Project cost: KRW 10.73 trillion → KRW 18.4358 trillion (KRW 12.7377 trillion in the first stage)
- Project implementation method: Divided into stages 1 and 2, implemented step by step
- Construction period: '92.6 - 2002.5 → 2004.4. (Phase 2 completed in 2010)
- Financing plan: No change

※ `98.8.6. : Notice of change in basic plan (Ministry of Construction and Transportation Notice No. 1998-259)

1999 18.Jul.99.
Establishment of high-speed rail system name:
- Korean: 'Korea High Speed Rail'; English: 'KTX' (Korea Train Express);
22.Nov.99.
High-speed rail noise standards confirmed (agreement with the Ministry of Environment):
- Test line section 65~70dB; section outside the test line 63~68dB; 15 years after opening 60~65dB
16.Dec.99.
Gyeongbu high-speed rail test operation began:
- Section: Sojeong-myeon, Yeongi-gun, Chungnam ~ Hyeondo-myeon, Cheongwon-gun, Chungcheongbuk (34.4km);
- Test run speed: 200km/h

2000 13.Nov.00.
- Test line section (Eumbong-myeon, Asan-si, Chungcheongnam-do to Hyeondo-myeon, Cheongwon-gun, Chungbuk, 57.2km) completed and test operation at 300km/h commenced;
- Rated as "A" by the National Science and Technology Commission

2001 - Rated as "A-Grade" by the National Science and Technology Commission

2002 Jun.02.
- Manufacture and assembly of 7 prototype vehicles completed: factory test run;
Aug.02.
- Commencement of test operation of test line section of prototype vehicle;
Aug.02.
- Determination of project implementation policy and designation of dedicated agency;
Dec.02.
- Research institute contest/selection and 1st year agreement/research commencement

2003 Feb.03.
- Development vehicle due diligence, final evaluation result evaluated as "Success" 1
23.Feb.03.
- Technology transfer completed
Sep.03.
- Announcement of successful 300km/h test run of Korean high-speed train

2004 Jan.04.
- Selected as one of Korea's top 10 new technologies in 2003;
24.Mar.04.
- Opening of Honam Line Double Track railway;
1.May.04.
- Gyeongbu High-Speed Railway Gyeongbu-Honam Line opened;
Dec.04.
- Successful test run of Korean high-speed train at 352.4 km/h

2005 Feb.05.
- Ministry of Construction and Transportation/Korea Railway Corporation/Korea National Railray launched a 'Driving Group of Willing Participants';
Mar.05.
- Lioyd's Rgister, UK, certified 350 km/h driving performance;
Nov.05.
- Exhibition of technological achievements at the 'Future Growth Dynamics Research Results Exhibition;
- Achieved mileage of 120,000 km

2006 Jun.06.
- Korean high-speed train successfully commercialized by signing a purchase contract

2010 - (Opening of high-speed rail) Gyeongbu Phase 2, existing Suwon Station used

2011 - (Opening of high-speed rail) Gyeongjeon Line

2012 - (Opening of high-speed rail) Jeolla Line

2014 - (Opening of high-speed rail) Incheon Airport, Honam New High-Speed Line, Donghae Line

2015 31.Mar.15.
- Pohang KTX (38.7km) opening ceremony;
2.May.15.
- Honam Line Osong-Gwangju Songjeong high-speed rail line (182.3km) opened (Opening ceremony: April 1, 2015);

2015	24.Jun.15. - Metropolitan High-Speed Railway Yulhyeon Tunnel construction ceremony; 31.Jul.15. - Gyeongbu High-Speed Railway Phase 2 (Daejeon-Daegu downtown section) opening ceremony; 30.Nov.15. - Wonju-Gangneung Railway Daegwallyeong Tunnel (Korea's longest mountain tunnel) construction ceremony
2016	15.Jul.16. - Gyeongjeon Line Jinju-Gwangyang (51.5km) opening ceremony; 22.Aug.16. - Succeeded in test operation of 300km/h metropolitan high-speed railway; 6.Oct.16. - Wonju-Gangneung railway construction final tunnel (Gangneung Tunnel) construction ceremony; 9.Dec.16. - Suseo High-Speed Railway (SR) 61.1km opened (Opening Ceremony: 2016.12.8.) * Introduction of competition system for the first time in railway history
2017	21.Dec.17. - Seoul-Gangneung KTX opened 120.7km route between Wonju and Gangneung
2020	2.Mar.20. - Gangneung Line KTX extended service to Donghae Station
2021	5.Jan.21. - KTX-Ieum operation began between Cheongnyangni and Andong on the Jungang Line; 31.Dec.21. - KTX-Eum operation began between Bubal and Chungju on the Central Inland Line
2022	20.Sep.22. - KTX number of users exceeded 900 million
2023	31.Aug.23. - Number of KTX users exceeded 1 billion: Achieved in 19 years and 5 months; 28.Dec.23. - Extended service to Central Inland Line KTX-Eum Pangyo Station; 29.Dec.23. - Gyeongbu Line: Mulgeum Station KTX New Stop; 29.Dec.23. - Extended operation of Jungang Line KTX-Eum to Seoul Station

References

[National Policy and Statistics]

- National Transportation DB (2018), Passenger Traffic Status INDEX BOOK.
- National Transportation DB (2018), Transportation according to Statistics.
- National Statistics Portal, "Population by Administrative District (City, County, District), Gender" (http://kosis.kr/statHt ml/statHtml.do?orgId=101&tblId=DT_1B040A3&conn_path=I3).
- Microdata Integration Service, 「National Business Survey」 (https://mdis.kostat.go.kr/extract/extYearsSurvSearchNew.do?curMenuNo=UI_POR_P9012).
- National Statistics Portal, 「GRDP (City/County/District)」 (http://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1C65_03E&conn_path=I3).
- Ministry of Land, Infrastructure and Transport (2016), Railway Statistics.
- Ministry of Land, Infrastructure and Transport (2020), 2019 Road Traffic Statistics Yearbook.
- Korea Transport Institute, National Transport DB Center (https://www.ktdb.go.kr), National Inter-regional Transportation O/D.
- Korea Railroad Corporation, Annual Railway Statistics Yearbook.
- Korea Railroad Corporation (http://www.letskorail.com/ebizprd/prdMain.do , 2023.05.01.).
- Based on travel time between express/intercity bus terminals (map.naver.com, 2023.05.01.)
- Gwangmyeong City (http://www.gm.go.kr/pt/partInfo/ud/local_develop/PTMN326.jsp, 2020.12.13.).
- Korean Air (https://www.koreanair.com/?hl=ko, 23.05.02).

[Books, Research Reports, etc.]

- Railway Administration. (1999). Jeolla Line Improvement Railway Construction Site (Sinri-Dongsuncheon)
- National Railroad Corporation. (2011). Gyeongbu High Speed Rail Construction History (I , II , III-1, III-2)
- Jeolla Line Railway Co., Ltd. (2012). Jeolla Line Iksan-Sinri Double-track Railway Private Investment Facility Project Construction Site
- National Railroad Corporation. (2013). Gyeongjeon Line Samnangjin~Jinju Construction Site
- National Railway Corporation . (2016). Honam High-Speed Railway Construction History (I , II)
- National Railroad Corporation. (2017). Metropolitan Area High-speed Rail Suseo~Pyeongtaek (Volume I, Volume II)
- National Railroad Corporation. (2018). Wonju-Gangneung Railway Project Construction Site
- Gyeonggi Research Institute (2010), "Does the straw effect of GTX exist?"
- National Railroad Corporation/Korea Transport Research Institute (2020), High-speed Rail Opening Effect Analysis Service.
- Research Institute for Human Settlements (2003), Study on prospects for changes in national spatial structure and response measures following the opening of high-speed rail.
- Jihye Kim (2023), Diagnosis of the current status of railway services and railway policies for regional development; Paper at the Spring conference of the Korean Society of Transportation Policy and Economics.
- Korea Transport Institute (2010), "Survey and analysis of KTX usage status and regional economic impact."
- Korea Transport Institute (2016), "12 years since the opening of the high-speed rail, what has changed?"
- Korea Transport Institute (2016), 2016 KTX Economic Zone Specialization Development Support Project.
- Korea Transport Institute (2018), "Analysis of regional economic impact according to high-speed rail service supply level."
- Korea Transport Institute (June 2019), "Explanatory material for distribution of basic data for transportation demand analysis."
- Korea Transport Institute (2020). 2020 Transportation Industry Job Information Survey Project.
- Korea Transport Institute (2021), 2021 Transportation Industry Job Information Survey Project (Vol. 2. High-speed Rail Usage Characteristics and Rail Service Demand Survey).
- Korea Railroad Authority (May 2011), Gyeongbu High-Speed Railway Construction History.
- Korea Environmental Policy Evaluation Institute (2002), Comparative Analysis of Environmental Performance of Land Transportation.
- KDI (2017), Research on Benefit Calculation Methodology for Transportation Sector Projects.
- KDI Public Investment Management Center (October 2020), Data from the 2nd preliminary feasibility study launch meeting in 2020.

[Academic Articles, Journals, etc.]

- Gyeong-taek Kim and Jeong-hoon Kim (2018), Observations on socioeconomic spatial structure by industry around stations considering proximity to high-speed rail stations, Journal of Korean Public Administration, 30(3), pp.627-650.
- Go Young-seon (2013), The impact of the opening of high-speed rail on the prices of apartments near the Daejeon subway station, doctoral thesis, Mokwon University.
- Daegu-Gyeongbuk Development Institute (2009), The effect of the opening of KTX on the economy of the Daegu region.

- Seo Won-seok, Moon Chae, and Yang Gwang-sik (2015), A study on time-series changes in the industrial structure of stationary cities according to KTX operation: Focusing on the Gyeongjeon Line and Jeolla Line, Journal of the Korean Society for Regional Development, 27(2), pp.139-154.
- Moon In-seok, Kim Eui-jun, and Lee Yu-jin (2017), Analysis of the economic effects of high-speed rail construction between Seoul and Gangneung: Focusing on the computational general equilibrium model, Journal of the Korea Regional Development Society, 29(1), pp.179-202.
- Seo Eun-young (2014), Analysis of factors influencing the characteristics of land price changes by land use around subway stations before and after the opening of high-speed rail, Hanyang University doctoral thesis.
- Koji Yoshimoto, Janghyun Kim, and Ilhyeon Bae (2016), A study on the impact of the opening of high-speed rail on revitalizing the regional economy: Focusing on the case of the opening of the Hokuriku Shinkansen in Japan, Journal of the Korean Society of Logistics, 26(3), pp.25-33.
- Seong-Woo Lee, Jin-Gyu Jeong, Woo-Seok Ji, and Jo Jung-Gu (2004), The impact of high-speed rail on population distribution in national territory, National Territory Research, 40, pp.3-17.
- Seong-Woo Lee and Il-Hong Jeong (2011), High-speed rail and regional disparities: Focusing on population changes between regions, Korean Regional Economic Research, Vol. 20, pp.61-79.
- Jeong Il-hong and Lee Seong-woo (2011), Empirical analysis of population movement by national territory following the opening of the KTX, Regional Studies, 27(3), pp.121-138.
- Nam-geon Cho, Hoon-ki Lee, Si-hyeon Jin (2005), Analysis of the straw effect following the opening of high-speed rail: Focusing on shopping traffic, National Territory Research, 47, pp.107-123.
- Jae-wook Cho and Myeong-je Woo (2014), The impact of the opening of high-speed rail on the regional economy and balanced development: Focusing on the KTX Gyeongbu Line and Gyeongjeon Line in Korea, National Land Planning, 49(5), pp.263-278.
- Choi Jin-seok (2014), The impact of KTX on the national economy, Railway Journal of the Korean Society of Railways, 17(2), pp.29-34.
- Hong Gil-ho (2018), Study on changes in regional development following the construction of the Gyeongbu High-Speed Railway, Master's thesis at Korea National University of Transportation.
- Seong-jo Hong and Yong-geon Kim (2017), Forecasting regional economic changes in Gangwon-do following the opening of high-speed rail, Journal of Urban Administration, 30(3), pp.47-72.
- Hong Soon-ho (2010), Study on analysis of the impact of high-speed rail (KTX) opening on regional economic growth, Hanyang University master's thesis.
- Albalate, D. (2022), Campos, J. and Jiméndez, JL, Local tourism effects of HSR in small cities: three synthetic control case studies, Current Issue in Tourism.
- Blum, U., Haynes, KE, and Karlsson, C. (1997), Introduction to the special issue The regional and urban effects of high-speed trains, Annals of Regional Science, 31(1), pp.1-20.
- Bonnafous, A. (1986), The regional impact of the TGV, Transportation, 14, pp.127-137.
- Boto-García, D. and Pérez, L. (2023), The effect of high-speed rail connectivity and accessibility on tourism seasonality, Journal of Transport Geography, 107.
- Chen, G. and Silva, JA (2011), The regional impacts of high speed rail: a review of methods and models, Transportation Letters: the International Journal of Transportation Research, 5(3), pp.131-143.
- Chen, X. (2013), Assessing the impacts of high speed rail development in China's Yangtze River Delta megaregion, Journal of Transportation Technologies, 3, PP.113-122.
- DB International GMBH (2011), High Speed Rail as a tool for regional development, étude approfondie, 8 août.
- JR West Japan (2015), West Japan analyzed with Data.
- Kim, JH, Lee, JH, and Lee, JH (2010), Changes in healthcare utilization of cancer patients since the launch of KTX, Journal of Korean Society for Railway, 13, pp.236-243.
- Kim, JH, Lee, JH, Ryu, WG, Bang, SA, Kang, SD, Lee, JH, Kim, MS and Ryu, YK (2008), Health impact assessment of high speed train (KTX) in Korea, Technical report , Korea Institute for Health and Social Affairs.
- Kobayashi, Kiyoshi & Makoto Okumura (1997), The growth of city systems with high-speed railway systems, The Annals of Regional Science, 31(1), pp.39-56.
- Lee, JH, Lee, W. and Jung, H. (2011), Determinants of bypass healthcare utilization for hospitals in Seoul: The case of KTX passengers, Journal of Korea Contents Association, 11, pp.259-274.
- Ollivier, G., Ying, J., Bulock, R., Runze, Y. and Nanyan, Z. (2014), Regional Economic Impact Analysis of High-Speed Rail in China, Report for the World Bank and the People's Republic of China.
- Rietveld, P., Bruinsma, F., Van Delft, H., and Ubbels, B. (2001), Economic Impacts of High Speed Trains: Experiences in Japan and France.
- Sasaki Komei, Tadahiro Ohashi & Asao Ando (1997), High-speed rail transit impact on regional systems: does the Shinkansen contribute to dispersion?, The Annals of Regional Science, 31(1), pp.77-98.
- Seeda - South East England Development Agency (2008), HST Impact Study.
- Zhang, Ming, Qing Wu, Dianting Wu, Lin Zhao & Xi Liu (2014), Analysis of the influence on regional economic development of high-speed railway, Journal of Chemical and Pharmaceutical Research, 6(8), pp.243-254 .