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The Effect of the Introduction of the Express Highspeed Railway in Korea*

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Abstract

Purpose **–** In today's era of carbon neutrality, railways need to find ways to improve usability and efficiency. Accordingly, this study examines the effect of introducing express highspeed railways into the Korean public transportation system and suggests some practical guidelines. One concern in the Korea railway sector is that low scheduled speeds contrast with the highspeed railway system design.

Research design, data, and methodology **–** Current literature and foreign cases are analyzed. Subsequently, using data from the Korean Railroad Research Institute, a benefit analysis is conducted based on expanded track capacity and the saving of time owing to the introduction of the express highspeed railway.

Result **–** The express highspeed railway system is expected to increase the number of train lines from 262 to 348 and the scheduled speed from 168.3km/h to 192.2km/h. Considering reduced time value, the economic effect is about 80 million won per year.

Conclusion **–** The findings suggest that the express highspeed railway is a promising option to improve efficiency and increase customer utility. This study contributes to the literature by initiating a discussion on the express system in Korea; practically, it offers railway operators guidelines for improving highspeed railway system efficiency that can be transformed into a variety of marketing options.

Keywords: Express Railway, Highspeed Railway, Rail Introduction Effect, Korea

JEL Classification Code: L92, M10, M38, R42.

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1. Introduction

Today, finding ways to improve highspeed railway infrastructure usability and operational efficiency is particularly important in this era of carbon neutrality. However, new construction investment in national state-owned companies (SOCs) like railways has become constrained by the impact of the expenditures related to the coronavirus pandemic (COVID-19); at the same time, network complexity has increased as urban/metropolitan railways have expanded. Amid social problems, such as poor public transportation operator management resulting from COVID-19 and congestion from the increased number of passenger cars, faster and more efficient transportation must be expanded. to improve public transportation systems. The gas that many cars emit into the atmosphere has caused global warming and climate change (Woo, 2021). The revitalization of railway services is also very important in that it is an eco-friendly means of transportation.

In Korea, a low scheduled speed is frequently a major problem for its highspeed railway. The average scheduled speed of the Korean Train eXpress (KTX) (including stopping time) is about 168 km/h, which is about 28 km/h slower compared with Japan's express train, the Japan rail (JR)-East Japan Hikari at 196 km/h. Several overseas highspeed railways, such as Japan's JR-East Japan and JR-Central, Taiwan's Highspeed Railway, China's Wuhan-Guangzhou Highspeed Railway, and Germany's ICE-Sprinter, achieve high scheduled speeds by successfully operating express trains. Although Korea's highspeed railways already have sub-mainline facilities necessary for express operation, they have been unable to begin operating express highspeed railways because of bottlenecks in the Pyeongtaek-Osong track capacity. However, the recent Pyeongtaek-Osong double track project is expected to resolve the bottleneck in the Gyeongbu Highspeed Railway track capacity. Thus, this represents an opportunity to innovate the Korean highspeed railway operation system, focusing on express highspeed trains to improve the scheduled speed and diversify services.

Unless a comprehensive advance plan is created for introducing and operating express highspeed railways, huge infrastructure replacement costs will be incurred in the future owing to the nature of the express operation system. Therefore, various analyses of the express train operating system are required to prevent this. To support the dual goals of increased usability and improved efficiency, this study investigates the effect of introducing express highspeed railways in Korea. First, we review the literature on the current status of highspeed railways in Korea and survey cases of overseas highspeed railway operations. Then, we examine the expected effect of the introduction of the express highspeed railways as an economic benefit created by the saving of time.

This study is different from previous studies in that we discuss the concept of "express" in terms of highspeed trains, which has rarely been mentioned in Korea before. Express trains are already in operation in Korea's metropolitan and urban railroads, but discussions have not yet begun on Korea's highspeed railways for various reasons such as track capacity. This study is different from previous studies also in that in that we offer suggestions for railway infrastructure managers and railway operators that can help advance their project preparations.

Introducing express trains will bring many changes in Korea's highspeed railway market in terms of infrastructure, construction, and customer service. In terms of railway infrastructure management, infrastructure and parts insufficiencies will need to be addressed before express highspeed railways can be introduced. Additionally, railway operators will need to enhance their operating systems, which become more complex with the introduction of express highspeed railways; they will also need to consider a rate differentiation policy based on this.

2. Literature Review

2.1. Korean studies on express highspeed railways

Low scheduled speed has been a significant issue in Korea's highspeed railways. The maximum speed of the Gyeongbu Highspeed Railway in Korea is 300km/h, but the average scheduled speed is 168.3km/h, which is 27km/h slower than that of the Japanese highspeed trains mentioned above. Although Korea's highspeed railways are already equipped with the facilities necessary for operating express highspeed trains, such as evacuation line facilities and highspeed track converters, they have yet to be used.

Most studies on Korean express trains have focused on the urban and metropolitan railways, with few addressing highspeed railways. However, studies on highspeed railway scheduled speed improvement have addressed the express train concept at times.

Previous studies on urban and metropolitan railways in Korea include the following. The Seoul Institute (2001) conducted an effect assessment of combining slow and express operations in the context of introduction of express trains, but ignored technical feasibility. The Korea Transport Institute (2011) conducted both a technical review and

an effect analysis, presenting short-, medium-, and long-term business directions based on an operation plan feasibility assessment for each axis in Seoul and other metropolitan areas. The Korea Railroad Research Institute (2014) studied train technology and infrastructure improvement related to express trains and conducted economic analyses for each line and alternative. The Korea Railroad Research Institute (2018) also designed a future metropolitan railway network considering the metropolitan express railway (GTX) and the New Ansan Line. It estimated traffic pattern changes based on the formation of such highspeed networks as foundational research for strategies for turning existing urban and metropolitan railways into express railways. Table 1 summarizes previous studies on urban railways and turning metropolitan railways into express railways (The Korea Railroad Research Institute, 2021).

Table 1: Studies on Changing Urban and Metropolitan Railways into Express Railways

Organization	Key Content
The Seoul Institute (2001)	- Technical review conducted on the premise that enhancements can be achieved through overseas case studies - Developed the effectiveness assessment method (operation assessment simulator) for operating five types of slow and express trains on existing lines on the premise of introducing an express line - Case studies on trainlines 3 (Ilsan line) and 2 and 7 - Proposed a step-by-step implementation plan
Korea Transport Institute (2011)	- Conducted technical review and effectiveness analysis - Reviewed feasibility of express train operation and direct mutual railway operation - Feasibility assessment of operation plan by axis in Seoul metropolitan area and other metropolitan areas - Proposed short-/mid-/long-term project directions
Korea Railroad Research Institute (2014)	- Researched turning existing metropolitan railways into express railways - Operation plan for express trains, train core technology, research on infrastructure improvement technology - Conducted economic analysis for each alternative route - Developed core technology for metropolitan express railway - Reviewed GTX and highspeed railway direct operation plan - Researched safety plan of GTX train/power system
Korea Railroad Research Institute (2018)	- Established a reasonable transportation demand forecasting method - Classified demand forecasting after securing the stability of basic data for demand forecasting

Source: Korea Railroad Research Institute (2021)

Studies by the National Railroad Corporation (2017) on express highspeed railways in Korea included an analysis of the Pyeongtaek-Osong double track project and improving the scheduled speeds of highspeed railways. Additionally, a preliminary feasibility study for increasing railway track capacity was done by KDI (2019) (an adequacy study for Pyeongtaek-Osong two-way double tracks); further, a feasibility study of the Pyeongtaek-Osong two-track construction project and a basic plan was completed by the Ministry of Land, Infrastructure and Transport (2020).

As mentioned, the infrastructure facilities for operating the express trains already exist in Korea. Additionally, evacuation lines and platform facilities for evacuating regular highspeed trains have been established at all highspeed railway stations, and highspeed track converters have been installed, allowing evacuation/passing within three minutes.

The GTX project is also actively underway in the metropolitan areas. To reduce commuting time, the metropolitan express railway project is being promoted, and related local governments have recently increased demand for route extensions and business expansion.

2.2. Foreign cases of express highspeed railways

Several countries abroad are operating express trains to improve the scheduled speed of highspeed railways. We look at the cases of Japan, Taiwan, Germany, and China to compare their feasibility with operations in Korea.

Table 2: Comparison of Scheduled Speeds of Korean and Japanese Highspeed Railways

	Gyeongbu Highspeed Railway (Gwangmyeong–Busan)	**JR East Japan Highspeed Railway Tokyo–Osaka**
Maximum speed (km/h)	300	285
Extended km/number of stops	395.4/8	552.6/17
Average inter-station distance (km)	49.23	32.5
Bottleneck operation headway	5.1 minutes (Cheonan Asan–Osong)	6.2 minutes (Tokyo–Mishima)
Scheduled speed (km/h)	Per single type: 168.3	Nozomi: 235.2 Hikari: 195.6 Kodama: 138.2

Source: Internal research report at Korea Railroad Research Institute

Examples of highspeed express trains in Japan include JR – East Japan and JR – Central (Tokaido New Main Line); for these trains, there is no significant differentiation between general and express fares. Table 2 shows the highspeed railway routes between Korea and Japan compared with the Gyeongbu Highspeed Railway and the JR–East Japan highspeed railway. The average scheduled speed of the Gyeongbu Highspeed Railway (168.3 km/h) is about 27 km/h slower than that of the Hikari Train (195.6 km/h) of the JR–East Japan Highspeed Railway.

Taiwan's highspeed railway is very similar to the operating structure of the Korean highspeed railways. Tables 3 presents the current status of Taiwan's highspeed railways. The Taiwanese highspeed railway line is 345km long and has 12 stations, and its express train has a standardized schedule deployed at a fixed time every hour. The average distance between stations in the Taiwanese highspeed railway is about 28km, which is more than 20km shorter than that of Korea's Gyeongbu Highspeed Railway. Additionally, the scheduled speed of the Taiwanese express train is about 197km/h, which is about 50km/h faster than that of general express trains.

Table 3: Comparison of Taiwan's Highspeed Railway Trains

Type	**Taiwan's Highspeed Normal Train**	**Taiwan's Highspeed Express Train**
Maximum speed	300	300
Extended km/number of stops	345km/12	345km/5
Inter-station distance	28.75	69
Operation headway	10 minutes (Runs 90 times a day)	Runs 15 times a day
Operating time	2h 25m	1h 45m
Fare	General 1530 Taiwanese dollars Business class 2500	General 1530 Taiwanese dollars Business class 2500

Source: Internal research report at Korea Railroad Research Institute

Unlike Japan and Taiwan, which do not differentiate fares between highspeed and regular trains, German and Chinese highspeed trains do differentiate fares for express trains.

In Germany, the train headway (train interval) between Berlin and Munich is about one hour, and the stops are interchanged according to time zone. Table 4 shows the current status of Germany's highspeed railway. We found that German railway fares and operating hours were variable, and its ICE Sprinter trains charged an additional fee of 11 euros compared with that of the ICE train.

Table 4: Comparison of German Highspeed Railways

	ICE	ICE Sprinter
Maximum speed (km/h)	300	300
Extended km/number of stops	540 km/10	540km/5
Inter-station distance	54	108
Operation headway	9-15 times a day	3-4 times a day
Operating time	4h20m	3h50m
Fare	50-120 euros	Additional 11 euros

Source: Internal research report at Korea Railroad Research Institute

Various types of express trains are also operational in China. The Beijing–Shanghai line (approximately 1,200 km), for example, has a train headway (train interval) of around 20-30 minutes between Beijing and Shanghai, and runs express trains with minimal stops (four stations) every hour. Express trains are about 1.5 hours faster than regular trains and cost about 12 yuan more, differentiating the fare based on the service.

3. Introducing Express Highspeed Railways in Korea

3.1. Anticipated effect of introducing the express highspeed railway in Korea

We can consider ways to improve the scheduled speed of express trains in Korea, focusing on express highspeed trains, by utilizing the existing infrastructure installed for Korea's highspeed trains and developing express train operating technology. First, we can reduce highspeed railway users' travel time by improving highspeed railways' scheduled speeds, thereby increasing user satisfaction and numbers. In addition, we can expand areas benefitting from highspeed railways and increase user numbers by building new stations for highspeed railways in the middle of the long distances of express highspeed trains.

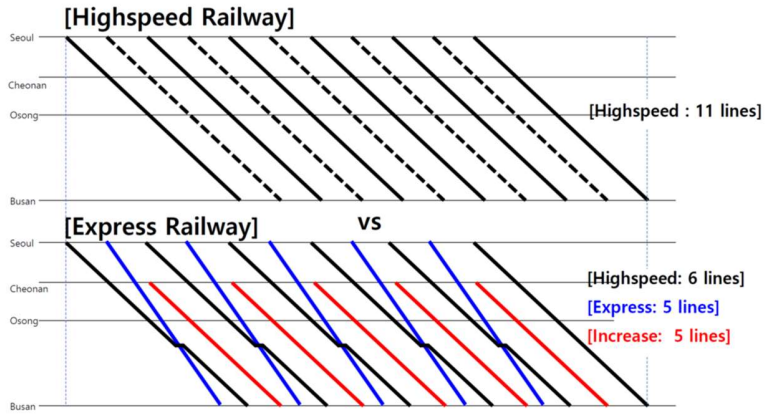

Figure 1: Conceptual Diagram of Express Highspeed Railway Operation

In the case of express highspeed trains, we can also reduce the current travel time from 160-167 minutes by 20-27 minutes (12.5-16.2%) by maintaining the Seoul–Busan travel time to within 140 minutes. The expectation is that highspeed railway passengers will increase based on the reduced travel time offered by the express highspeed trains.

Moreover, there is the potential to differentiate services for users of regular and express highspeed trains and introduce different fares.

The introduction of highspeed express trains can dramatically increase the number of operation times. While there are six regular operations currently, once the two-way double track is working, train operations can increase to 11 by increasing track capacity. Additionally, when express trains are introduced, these trains can be employed five more times in addition to the six regular trains and five express trains. Figure 1 presents a conceptual diagram of the express highspeed railway operation. There is a study is to figure out how to apply the customer-based pricing approach to fares of new railway services using express trains (Kim & Kang, 2021).

Introducing express highspeed trains is also consistent with the direction of Korean government policy as last year, the Ministry of Land, Infrastructure and Transport (2021) created the Fourth National Railway Network Establishment Plan, 2021-2030. Important to the plan is introducing express trains on existing routes, connecting disconnected sections, and creating a basis for expanding railway operations centered on highspeed railways to improve operation efficiency. Securing a new highspeed railway operation system following highspeed railway route diversification is also an important task. Highspeed railway route diversification is already underway based on different plans. Examples include the opening of the Pyeongtaek-Osong two-way double track (planned for 2027) of the highspeed railway from Incheon and from Suwon (both planned for 2024). By operating express trains, we can improve the scheduled speed (27km/h) of highspeed railways, achieved by improving express train scheduling optimized software for existing urban and metropolitan railways.

Table 5 presents the results of the basic plan review of the two-way double track between Pyeongtaek and Osong in terms of track capacity and number of train operations; the number of train operations are 176 per day before the two-way double track and increases to 262 afterward. Once the highspeed express train are introduced, this number increases to 348.

Table 5: Results of the basic plan creating double tracks between Pyeongtaek and Osong

	Before implementation of the double tracks	**After implementation of the double tracks**	**After implementation of the express train**
Track capacity (one-way)	190	380	380
Number of trains (one-way)	176	262	348

Source: Korea Railroad Research Institute (2021)

3.2. Estimated benefit of introducing express highspeed railways in Korea

The benefits of introducing a highspeed express train and improving the scheduled speed of highspeed railways can be determined in various ways. Our analysis is based on calculating the benefit of reduced travel time.

The main data are from the 2020 Railway Statistical Yearbook. Table 6 shows that the passenger–km (number of people x ride distance) of highspeed railways was 21.2 billion in 2018, 22 billion in 2019, and 13.6 billion in 2020. The traffic volume fell dramatically in 2020 due to Covid-19, so in our analysis, we substituted passenger–km data from 2019.

Table 6: Passenger–km of the highspeed railway

Year	**Regular express railway passenger–km (passenger-km/year)**		**Non-regular highspeed railway passenger–km (passenger-km/year)**		**Sum**
	KTX	**SRT**	**KTX**	**SRT**	
2018	315,525,183	108,896,998	15,633,949,463	5,150,787,188	21,209,158,832
2019	348,416,164	50,396,363	16,332,374,186	5,341,352,952	22,072,539,665
2020	296,793,809	48,882,192	9,599,778,634	3,714,655,262	13,660,109,897

Source: Ministry of Land, Infrastructure and Transport (2021)

As stated, our analysis shows that the number of trains operated can increase from 3.1 to 176, reaching 262 after the two-way double tracks are in use, and 348 after introducing the express trains. We assumed that if express trains were operated after creating the double-tracks, train demand would increase in proportion to the number of routes. Benefits of reduced travel time per hour was set at 9,651 won based on references in KDI (2021).

To estimate the benefit of reduced travel time, the time saved was calculated by comparing the time per passenger–km at 192.2km/h once express trains were introduced with the time per passenger–km at the current 168.3 km/h. Table 7 presents the economic benefit result of introducing the express highspeed railway. Creating the two-way double track between Pyeongtaek and Osong results in a reduction of approximately 32 million hours annually, saving 310 billion won.

Table 7: Economic Benefits of Introducing the Express Railway

	Present	**After creating double tracks for Pyeongtaek-Osong**	
		Before introducing the express train	**After introducing the express train**
Number of trips	176	262	348 (262+86)
Scheduled speed	168.3km/h	168.3km/h	192.2km/h
Highspeed railway passenger transport passenger–km (per year)	22,072,539,655	32,857,985,183	43,643,430,681 (32,857,985,183 + 10,785,445,498)
Total railway time (per year)	131,149.968	195,234,612	227,073,000
Time saved (per year)			32,246,255
Benefits of reduced travel time (9,651 won per hour)			311,208,607,005

4. Conclusion

Our study reviews and analyzes the rationale and effects of introducing express highspeed trains in Korea. We reviewed the existing studies on express trains in Korea as well as investigated overseas examples of express train operations. We then estimated the benefit of introducing these express highspeed trains and expanding track capacity in terms of saving time. Our analysis shows that these changes can produce a significant economic benefit for Korea.

There is an academic contribution that this study initiates the discussion on express train operation in Korea. Express highspeed trains are operated in many countries overseas, but in Korea they are only implemented in urban/metropolitan railways and not yet in a highspeed railway. With large-scale infrastructure, such as evacuation lines for introducing express trains on highspeed railways already in place, the introduction of express highspeed railways that can dramatically increase scheduled speeds can contribute significantly to Korea's national transportation system's development. However, as no discussions on highspeed trains have occurred yet, owing to bottlenecks in the Pyeongtaek-Osong railway section, this study can now serve as a reference for further discussions on the introduction of such express highspeed trains.

There is a practical implication that this study can provide Korea's highspeed railway operators with strategies for a system maintenance period and marketing ideas for operating express highspeed trains with differentiated fares. After introducing the two-way double track between Pyeongtaek and Osong, express highspeed train operations are expected to develop rapidly. To run such trains, we need to put in place varied and complex train schedules and shift away from the existing linear operations. Since substantial time is required for the realistic operation of the express highspeed train, railway operators, such as KORAIL and SR, will need to consider this issue as soon as possible. In addition, since introducing express highspeed trains presents a good opportunity to diversify marketing methods for

highspeed railways, such as fare differentiation, further analyses are needed along with in-depth discussions to increase railway operators' efficiency and profits.

Despite the theoretical and practical significance of this study, it has the following limitations. First, further analysis is needed on the exact value of the increase in track capacity. For this study, we used Korea Railroad Research Institute data to assume an increase in trains based on express trains. Since the train operation plan for the Pyeongtaek-Osong two-way double track has not yet materialized, the number of trains could change significantly depending on various hypotheses. When the Pyeongtaek-Osong two-way double track plan becomes concrete, the changes in track capacity and train numbers will need updating. Second, more diverse methods can be used for the economic benefit analysis. Our brief economic benefit analysis was conducted based on preliminary feasibility guidelines, and strong assumptions were used for changes in demand, additional costs, and saved travel time. In future research, developing a strict analytic tool and obtaining actual data to replace the relevant assumptions will be necessary. Third, different types of technology are required to introduce express highspeed railways. Examples include technology that can optimize express highspeed train operation using existing infrastructure following the two-way double track between Pyeongtaek and Osong; that optimizes the selection of additional highspeed railway station construction sites considering the advantages of long inter-station distances; that can verify and simulate operation schedules including express highspeed trains; that can verify availability of trains and garages according to express highspeed train operation within a competitive operating system; technology that can optimize fares/charges based on the introduction of express highspeed trains; and that can analyze changes in demand and benefits arising from the introduction of express highspeed trains. Future studies should discuss such the technologies needed for introducing express highspeed railways in detail and determine where more research and development is required.

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