Next Generation of Korea Train eXpress (KTX): Prospects and Strategies

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Abstract

Successful commercial operation of KTX in the high speed line (HSL) and conventional line (CL) had been started since April 1st, 2004. During KTX project of 12 years, Korea high speed railroad technology had overcome many technical difficulties and acquired many precious experiences in terms of interfaces of R/S and infrastructures. Those things were adapted and integrated to develop the Korean-style HST which has technically compatible system for existing infrastructures. The new high speed train had successfully completed the 350km/h test run and is commissioning to verify the full system reliability and safety. The major characteristics of KTX and the Korean-style HST is compared and the development plan of tilting trains and HST with distributed traction power are also discussed. And the strategic plan to export the Korean-style HST to the world market is introduced. As it does, according to opening the KTX from Seoul to Busan, we have to think what the next step is. Like other countries of developing the high speed rail system, we have to try to export some kinds of system for further technology and industry development.

1. Introduction

The Korean railway industry has been actively discussing its revitalization since the successful launch of the high-speed railway (HSR) system along the Gyeongbu corridor from Seoul to Busan. The discussion was also triggered by various changes such as the development and commissioning of the Korean-style high-speed trains (HST), the development of tilting trains, the next-generation HSR project with distributed traction power system, and the increased role of the railway system as a transportation mode to resolve the issues of environment, energy and transportation difficulties. Besides, the railway industry is reviewing from various aspects the measures to serve as an engine for national economic growth and nurture it as a strategic export industry. In particular, the launch of the Korean HSR system has not only decreased logistics burden on the Gyeongbu corridor but also significantly transformed the Korean trunk-line railway network, revolutionizing the logistics and technology sectors and reinvigorating the Korean railway industry in one century. Initially, the HSR project intended to construct new line through whole sections from Seoul to Busan along the Gyeongbu corridor. However, the initial plan was modified from the new line through the whole sections between Seoul and Busan to the step-by-step revenue service plan which electrifies the Daegu-Busan and Daejeon-Mokpo existing lines for the direct operation KTX. This successful operation of KTX system in the high-speed line and conventional lines is the application of KTX system technology transferred and of an achievement of smooth system interface with the KTX system and conventional railway system. The HSR system interface and engineering technologies accumulated during the project have brought about a remarkable improvement in the existing railway system in terms of design and engineering technologies of high-speed trains and existing railway infrastructure, not to mention the new HSR lines.

Given the circumstance, the paper aims for enhancing the international competitiveness of the Korean HSR industry based on the technological achievements and operational experiences accumulated through the KTX project. Thus, the paper looks into the measures for the industry to continue its growth and gain technological competitiveness in the overseas market mainly by developing diverse train systems creating high value-added. To be more precise, the paper reviews the Korean-style HST that have adopted new technologies along with the conventional ones to achieve the target operation speed of 350km/h; the Korean-style tilting trains with the speed of 180km/h; and the next generation HST with distributed power traction system.
2. National Railroad Network Plan in Korea

A. Railway Network Plan

The National Inter-modal Transportation Network Plan (2000-2019) includes the establishment of a cross-national, X-shaped HSR network and its connection to the Trans-China and Trans-Siberia Railways to form an Eurasia continent railway network. According to the Plan, the current trunk lines will be transformed into double-track, electrified lines, and in the long term, the operation speed on them will be increased to 180 km/h for connection with the newly constructed HSR. The Plan defines a vision for the 21st century national railway network: “construction of a railway system that conforms to the concept of G-transportation (global transportation) and the open structure of national territory, and contributes to the decentralized development of national territory, high-speed access between regions and management independence.”[1]

To achieve this vision, a hierarchy has been introduced in the railway system in order to use the economy of scale in terms of facilities and secure efficiency in facility operation, both of which are necessary as the case of road system (see Table 1). As a result, the national railway network is divided into eight categories:
1) lines to facilitate a balanced development of national land and the decentralization of transportation structure: development of new corridors, and lines that regional autonomous governments ask for;
2) lines to realize high-speed access between regions;
3) lines to resolve various transportation issues;
4) lines to enhance connection between the HSR and other transportation modes: lines connecting the HSR and the conventional railways, and lines to enhance accessibility to the HSR stations;
5) lines to increase the efficiency of the logistics system: lines focusing on freight transportation between regions, and lines connecting ports, freight terminals and industrial complexes;
6) lines to connect with the Eurasia continent: lines connecting the South and North Korean railways, and lines for a future connection between Trans-Korean and Trans-continental railways;
7) lines to improve the transportation systems in megalopolitan areas; and
8) lines to enhance accessibility to a new administrative capital.

This categorization has produced 48 railway lines, for which roles and project budget and duration have been set up. Also, based on the categorization, 13 corridors have been drawn in the national railway network (seven north-south corridors and six west-east corridors).

<table>
<thead>
<tr>
<th>Category</th>
<th>Functions and Roles</th>
<th>Track Class</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk lines</td>
<td>Connection between major cities</td>
<td>First</td>
<td>Double-track electrified railway</td>
</tr>
<tr>
<td>Branch lines</td>
<td>Connection between trunk lines and medium- or small-cities</td>
<td>Second</td>
<td>Single- or double-track electrified railway</td>
</tr>
<tr>
<td>Megalopolitan lines</td>
<td>Operation within megalopolitan areas</td>
<td>Third</td>
<td>Double-track electrified railway</td>
</tr>
<tr>
<td>Industrial lines</td>
<td>Connection between ports and industrial complexes</td>
<td>Fourth</td>
<td>Single-track electrified railway</td>
</tr>
<tr>
<td>Trans-continental &amp; Trans-Korean lines</td>
<td>Connection between Trans-Korean &amp; Trans-continental lines</td>
<td>First</td>
<td>Double-track electrified railway</td>
</tr>
</tbody>
</table>

Table 1. Targeted Facility Level by Railway Lines in Hierarchy System

In another study[2], various issues were reviewed including government policy directions concerning the operation of railway rolling stocks, diverse strategies to secure financial resources, and reasonable government support models and indexes. The study was to reflect the changes in the domestic railway industry and smoothly provide transportation services according to the National Railway Network Plan.

3. Current Status of Train Technology Development in Korea
A. Development of High-speed Trains

The HSR project for the Gyeongbu corridor started in 1992 and the first phase of the project was completed in April 2004. During the first phase, while new line was constructed for the section between Seoul and Daegu, conventional lines were electrified for the Daegu -Busan section (Gyeongbu line) and the Daejeon--Mokpo section (Honam line), aiming a simultaneous opening for commercial operation. Currently, HSTs are operated at the speed of 300 km/h on the Seoul -Daegu section and 140km/h on the Daegu-Busan and Daejeon-Mokpo sections. The Gyeongbu HSR construction was one of the largest national projects, with the investment of 1.27 billion dollars for the 13 years of the first phase of the project. As for the Honam line, a total of 875.3 million dollars was invested to electrify the Daejeon-Mokpo existing section.

For the Gyeongbu HSR project, Korea adopted French TGV as its rolling stock model, and thus most of the KTX system design is similar to that of the French system. The original French system was adapted to fit the Korean environments so technical innovations were limited to those strictly needed to meet special contractual requirements. While this approach contributed to the early stabilization of the KTX system, it made difficult for Korean engineers to have an access to essential technologies applied in the KTX system.

Although Korean experts conducted the in-depth preliminary and final design reviews, their insufficient knowledge about the HSR system made it difficult for them to closely look into system interface issues at the initial stage. However, as the project proceeded, Korean engineers were able to accumulate knowledge about designs, manufacturing and evaluation of train sets through the local manufacturing, design qualification test and full system commissioning of the KTX system. So, de signing, analyzing and testing technologies essential to the independent development of HSR and system interfacing for various subsystems and components were established. In particular, a new concept such as RAMS based rolling stock system engineering was introduced: different RAMS targets were established for important sub-systems and traced in order to secure a certain level of system performance. This has led to the establishment of procedures and standards with which the HSR system can be evaluated in terms of reliability, availability, maintainability and safety (RAMS).

The smooth operation since the launch of the KTX system has been largely due to the systematic interface control management between the HSR trains and infrastructure such as tracks, bridges, tunnels, and power supply, signal and communication systems. Thanks to the overall stability, Korea has become internationally acknowledged in terms of its technologies of constructing and operating the HSR system. The Korean-style HST, G7, was the result of combined efforts from various sectors that were involved in the construction and operation of the HSR project: local manufacturer’s manufacturing technologies, operator’s operation experiences, research institute’s studies on key technologies, and the government’s intensive investment in R&D.

B. Development of Tilting Trains

Along with preparation for the commercial operation of the KTX trains, considerations were given on providing enhanced services to the areas beyond the reach of the HSR system. For the conventional lines with the maximum speed of 140km/h were placing a limit on improving the efficiency of the national railway as a whole. Consequently, it was strongly required to increase the speed of the conventional lines for various purposes such as balanced development between regions, conventional lines’ integration into the HSR system, and railway system’s higher transportation efficiency.

In order to increase the operation speed on the conventional lines without changing the tracks, electric tilting trains are scheduled for development by 2006 and their commissioning is planned for 2007 and 2008. If successful, the tilting trains will run at the maximum speed of 180km/h reducing the running time on the major branch lines by 30 percent. At present, Korean-style tilting trains have the design speed of 200km/h (maximum speed: 180km/h) and one train set is composed of six cars. As for the hybrid car-body, stainless steel has been used for the under-frame and molding technology was adopted to make the sides and roofs of the trains out of all-composite material. In addition, tilting bogie systems were developed to enhance passengers’ comfort on the curve sections of the conventional lines and tilting pantographs (high-capacity current collectors) were applied. Also started were the development of technologies to integrate the electric tilting trains with existing track facilities and power supply and signaling system. If the tilting trains are successfully developed and placed into commercial service, diverse combination of trains with different speeds will be possible in the national railway network, enhancing the level of passenger services and transportation efficiency of the conventional lines.
4. Next Generation of Korea Train eXpress (KTX)

A. G7 Project

The G7 project started under the aim of upgrading the HST technologies transferred from France, rather than simply following them. The technology transfer was conducted under the 1993 agreement between Core System Engineering of Korea and EUKORAI L, a consortium led by the French company ALSTOM. Since its successful development of Korean style HST with the speed of 350km/h for the fifth in the world in 2002, Korea has been continuously conducting the commissioning of the trains to check their RAMS (reliability, availability, maintainability and safety). Until now, the trains have been test-run for the total distance of 130,000 kilometers and are expected to be placed into commercial service in the foreseeable future. According to its own judgement, Korea has reached a certain level concerning designing, manufacturing and evaluating of HSR systems through the G7 project, sufficient to advance into the international market for itself.

The Korean-style HST, designed and manufactured solely by local engineers (localization rate of 92%), has adopted advanced technologies from home and abroad and is considered to be comparable to other world-class HST. More significantly, essential components have been localized as well: 1100kW induction motors and propulsion control system using IGCT power semiconductors in the third and first in the world respectively.

The table below shows the technological differences between KTX and the Korean-style HST, G7.

<table>
<thead>
<tr>
<th>Features</th>
<th>KTX</th>
<th>G7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed</td>
<td>300km/h</td>
<td>350km/h</td>
</tr>
<tr>
<td>Formation of a train-set</td>
<td>20 cars</td>
<td>7 cars</td>
</tr>
<tr>
<td>Material of car body</td>
<td>Mild steel</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Traction motor</td>
<td>Synchronous</td>
<td>Asynchronous</td>
</tr>
<tr>
<td>Propulsion system</td>
<td>PFC + Phase control converter + Current source Inverter VVVF control (PWM control)</td>
<td>PWM control inverter + Voltage source inverter VVVF control (Vector control)</td>
</tr>
<tr>
<td>Power device</td>
<td>GTO</td>
<td>IGCT</td>
</tr>
<tr>
<td>Traffic control system Type</td>
<td>Analogue Friction + Rheostatic Regenerative breaking</td>
<td>Digital Friction + Rheostatic + Regenerative + Eddy Current breaking</td>
</tr>
<tr>
<td>Blending</td>
<td>Blending the electric and air brake in motor bogie</td>
<td>Blending the electric and air brake in motor bogie + Blending between motor bogie and trailer bogie</td>
</tr>
<tr>
<td>Air-tightness system</td>
<td>Passive</td>
<td>Active (pressurization system)</td>
</tr>
</tbody>
</table>

Table 2. Comparison of Technical Characteristics between KTX and G7

B. Post-G7 Project

Korea is reviewing the possibility of developing a HSR system with distributed traction power by improving the technologies accumulated through the G7 project. This move is to sharpen the Korean industry’s competitive edge in the overseas market through continuous research and development and diversity enhancement. Another consideration is to secure and disseminate power distribution technologies suitable for the characteristics of the Korean railway system including line characteristics and transportation demand. In line with this, Korea is planning to develop a next-generation HST with the maximum speed of more than 350km/h and a distributed traction power system that is complementary to the current, centralized traction controlling. Once the development completed, Korea will endeavor to make inroads into the international market including the United States of America, China and Brazil in order to preoccupy the market with competitive advantages.
5. Prospects and Strategies

A. National Railroad Network Plan and High-speed Trains

To secure sufficient capacity that is required by the National Railroad Plan, the railway industry needs to establish mid- and long-term train purchase and operation strategies in compliance with railway construction and operation policies. Also, the planned railway restructuring places a need to modify current rolling stock strategies in order for the government and train operators to faithfully play their roles even after the restructuring. During a railway construction planning in particular, measures should be drawn up to reflect both train usage and procurement plans of train operators. In other words, train operators, based on their train operation strategies, should come up with measures to closely cooperate with project operators from the planning stage through to the opening of a railway system.

To be more precise, train operators should establish long-term train procurement plans reflecting both long-term national railroad network plans and plans for each railway line in order to suggest appropriate roles and schedules for each line. Also, based on the long-term railway plan, directions should be decided concerning the research and development of trains.

When the high-speed/conventional railway system plans are implemented by transforming the conventional lines into electrified double-tracks and constructing new lines, changes can be made on train operation patterns in the form of opening new lines and route changes. In addition, if the major trunk lines are electrified according to the national railroad network plan, current diesel rolling stocks will be gradually replaced by electric cars. Therefore, a new railway system should be developed considering all these changes, and the system development should be preceded by a close review of government’s investment resources. Otherwise, differences can occur in terms of operating lines and time, making it difficult to retrieve R&D investment.

B. Future Rail Market

The world railway market, except the construction sector, is currently estimated to be worth approximately 25 billion US dollars with the HSR sector amounting to six percent. As the market is expected to grow further by at least four percent, Korea considers that now is a good time to expand its presence in the overseas market with aggressive strategies. If the Korean railway industry can increase its world market share to ten percent, it will be able to create annual sales of more than eight billion dollars, serving as a major growth engine for the national economy – the world market has an annual worth of 70 billion dollars breaking down to 45 billion dollars for the construction market and 25 billion dollars for the rolling stock market with the HST making up six percent, or 1.5 billion dollars.

In other words, as the HSR sector can create high value-added and there is a growing demand for the HSR system, the Korean railway industry should focus on exporting HSR system in the long term. To successfully advancing into the world market, the railway industry should not spare its efforts in research and development (R & D) activities. This means that to be best prepared for a new market, decisions should, above all things, be made on market environment based on R & D. One of the measures could be to develop railway technologies considering policies and operation.

6. Conclusion

Major accomplishments from the Korean HSR project are enhanced understanding about HSR technologies and having laid the foundations for local technological development. Among other things, the Korean railway industry has accumulated a sufficient level of technologies concerning railway system engineering, commissioning, operation and construction through four years of experiences and by resolving various technological issues after the opening of commercial service. Now it is high time for the local industry to disseminate the technological achievements attained from the Gyeongbu HSR project and the world’s fifth development of Korean-style HST, and maximize the effects of the newly developed technologies. To these ends, the Korean-style HST (G7) will be placed into commercial operation in the local market, as additional train-sets are needed beside the current 46 KTX train-sets. Also, G7 trains will be evaluated in terms of reliability and safety during the operation. Once the commercialization proves successful, the local industry should challenge the international market with the G7 trains. In particular, huge demand is also expected for HST with a distributed traction power system, detailed strategies should be drawn up regarding the system and related technologies should be developed. As for the Korean-style tilting trains, a prototype is expected for completion in 2006 and its commissioning between 2007 and 2008.
However, more important thing is to secure the railway industry’s competitiveness. This is not to compete with other transportation modes but to enhance the industry in various aspects. In order to cultivate the competitive power, major trunk lines should be aggressively changed into HSR and practical technologies should be developed considering the railway network. To successfully advance into the international market, the Korean railway industry should analyze which technological advantages it has against its foreign competitors. Also, it should select the form of participation concerning overseas HSR projects (independently, under partnership, etc) and specify measures to penetrate into the world market. In addition, as it considers that opportunities are also present in other sectors such as commissioning and operation of HST, diverse and flexible approaches should be taken in deciding sectors and methods to gain access to the international market.

References