Experiencias Exitosas en la Implementación de Sistemas Ferroviarios a Nivel Mundial
Korea’s Experience in the implementation of Railway projects

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Korea Rail Network Authority
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1. Overview of KRNA
2. Performance of KRNA
3. Introduction of Korean HSR
4. Introduction of Speed up project
01 Overview of KRNA
1. Overview of KRNA


Current Structure of Railway Industry

- Railway policy & planning
- Investment program
- Safety regulations, etc.

- Railway construction
- Railway facility management
- Railway area development
- Training & consulting
- Oversea business

- Train operation
- Rolling stock management
- Commercial operation
1. Overview of KRNA

1–1. Korean Railway History

1894
6. 28
Railway Bureau launched

1899
5. 16
Gyeonggi Line opened

1905
1. 1
Gyeongbu Line opened

1906
4. 3
Gyeongui Line opened

1914
1. 22
Honam Line opened

1914
1974
Honam Line opened

1942
1992
Gyeongui Line opened

2004
4. 1
Honam HSR opened

2007
4. 1
Gyeongbu HSR opened

2015
4. 1
Gangneung HSR opened

2016
12. 2
Suseo HSR opened

2017
12. 22
Wonju-Gangneung Railway opened

2017
12. 3
Opening ceremony

2018
12. 22
Construction of Gyeongbu HSR begun

2019
1. 1
Korea Rail Network Authority established

2020
3. 1
Seoul Station

2020
4. 1
Pungse Railway Bridge

2020
6. 20
Construction of Gyeongbu HSR begun

2020
6. 1
Train commencing service on Gyeongbu Line

2020
6. 1
Construction of Suncheon Station and railway office

2020
9. 18
Gyeongin Line opened

2020
9. 1
Opening ceremony at Noryangjin Station

2020
12. 16
Jungang Line opened

2020
12. 16
Jesila Line opened

2020
12. 16
Jungang Line opened

2020
1894
6. 28
Railway Bureau launched

2020
1894
6. 28
Railway Bureau in Yongsan

2020
1899
5. 16
Gyeonggi Line opened

2020
1905
1. 1
Gyeongbu Line opened

2020
1906
4. 3
Gyeongui Line opened

2020
1914
1. 22
Honam Line opened

2020
1914
1. 22
Honam Line opened

2020
1936
1942
1914
1974
1992
2004
2007
2015
2016
2017
2020
Gwangju Songjeong Station

Geumgang Railway Bridge

Seoul Station

Pungse Railway Bridge

Korea Rail Network Authority established

Honam HSR opened

Gyeongbu HSR opened

Suseo HSR opened

Opening ceremony

Gangneung Station

Gangneung Station

Suseo Station

Yulhyeon Tunnel (52.3 km)
1. Overview of KRNA

1–2. General Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Korea Rail Network Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Organization</td>
<td>Government Agency</td>
</tr>
<tr>
<td>Total Budget</td>
<td>USD 8 billion</td>
</tr>
<tr>
<td></td>
<td>* Total Project Budget in 2019</td>
</tr>
<tr>
<td>Total Asset</td>
<td>USD 18 billion</td>
</tr>
<tr>
<td></td>
<td>* According to Independent Auditors’ Report 2018</td>
</tr>
<tr>
<td>Credit Rating</td>
<td>Domestic AAA, Moody’s Aa2, S&amp;P AA–</td>
</tr>
<tr>
<td>Number of Employees</td>
<td>1,800</td>
</tr>
</tbody>
</table>

Head Office
Location: 242, Jungang-ro, Dong-gu, Daejeon, Republic of Korea (Postal code: 34618)
1. Overview of KRNA

1–3. Organization

Organization Chart

- 7 departments (48 divisions), 1 research institute, 5 regional offices & 3 overseas offices
## 1. Overview of KRNA

### Business Areas

<table>
<thead>
<tr>
<th>① Railway Network Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>② Project Management</td>
</tr>
<tr>
<td>③ Railway Construction</td>
</tr>
<tr>
<td>④ Railway Facility Management</td>
</tr>
<tr>
<td>⑤ Training &amp; Consulting</td>
</tr>
<tr>
<td>⑥ Railway Area Development</td>
</tr>
<tr>
<td>(Transit Oriented Development)</td>
</tr>
<tr>
<td>⑦ Overseas Railway Project</td>
</tr>
</tbody>
</table>

### PM Capabilities

- Planning stage management
- Design control
- Construction management
- Interface management
- Verification & Commissioning Test

---

**Economical, safe and efficient railway**
Performance of KRNA
## 2. Performance of KRNA

### 2-1. Current Status of Projects

<table>
<thead>
<tr>
<th>Total length</th>
<th>4,261 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrified</td>
<td>3,155 km (74%)</td>
</tr>
<tr>
<td>HSR (Over 300km/h)</td>
<td>3 lines</td>
</tr>
<tr>
<td>Conventional railway &amp; Inter-city lines</td>
<td>34 Main lines &amp; 55 branch lines</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connection</th>
<th>Dist. between Stns</th>
<th>Finance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR (300km/h)</td>
<td>Major city points</td>
<td>About 40Km</td>
</tr>
<tr>
<td>Conventional</td>
<td>Major or midsized cities</td>
<td>About 20Km</td>
</tr>
<tr>
<td>Inter-City</td>
<td>Downtown–suburbs</td>
<td>About 2–7Km</td>
</tr>
</tbody>
</table>
2. Performance of KRNA

2–2. High Speed Railways (Over 300km/h)

**Gyeongbu HSR**
- Distance: 417.5km
- Budget: USD 20 billion
- Phase 1 opened in Apr. 2004
- Phase 2 opened in Nov. 2010

**Honam HSR**
- Distance: 249.1km
- Budget: USD 10 billion
- Opened in Apr 2015

**Suseo Metropolitan HSR**
- Distance: 61.1km
- Budget: USD 3.0 billion
- Opened in Dec 2016
2. Performance of KRNA

2–3. Conventional Railways

Completed Projects
- 83 Lines: 3,413.6km
- Electrified: 2,308km
- 343 Stations

Ongoing Projects
- Conventional lines: 29 projects (1,586.7km)
- Intercity lines: 8 projects (293.1km)
- Modernization of existing lines: Upgrading of track, signaling, catenary and etc. to increase speed up to 250km/h
2. Performance of KRNA

2–4. National Rail Network

Railways, connecting Korea into one

Korea Rail Network Authority (KRNA) will expand the total length of railways to 5,364 km by year 2026 to enable people to enjoy faster and safer railways. The railways that KRNA builds play a key role in opening a new era by facilitating movements of both people and goods and expanding people's activity spaces.

Railways, exceeding limits of speed

Becoming 5th country in the world to have 300 km/h high speed rail in 2004, Korea succeeded in test operation that recorded maximum operation speed of 421.4 km/h in 2013. The high speed rail network has greatly reduced travel times between cities bringing huge changes to people’s lives and has increased the role of rail transport thereby boosting the national competitiveness. About 50% of Korea’s population benefit from the high speed rail transport services at present. KRNA aims to increase this rate to 85% by 2026 and continues to enhance speeds of conventional railways. This is expected to bring economic benefits of KRW 140.21 trillion.
2. Performance of KRNA

2–5. Overseas Projects

<Overseas projects’ status> ('05~'17.12.31)

- **China HSR Project**
  - Supervision: 5 Projects
  - Consulting: 7 Projects
- **USA California HSR Project**
  - Consulting: Presino~Bakersfield
  - Length: 200 km
- **India HSR Project**
  - Consulting: Detail Design of HSR
  - Length: 527 km
- **Malaysia MRT Project**
  - PMC for Communication System
  - Length: 51 km
- **Nepal Railway Project**
  - F/S: Mbalam~Kribi
  - Length: 583.4 km
- **Paraguay Railway Project**
  - F/S: Asuncion~Ypacarai
  - Length: 44 km
- **Jakarta LRT 1st Phase Project**
  - EPC Procurement: Systems & RS
  - Length: 5.8 km

- **India Lucknow MRT Project**
  - GC: General Consulting
  - Length: 8.5 km

- **2005 China Starting Supervision**
- **2012 Malaysia MRT PM Consulting Service**
- **2014 Paraguay MRT F/S Service**
- **2016 Indonesia Jakarta LRT 1st Phase**
- **2011 Nepal Nepal Railway F/S Service**
- **2013 USA HSR Technical Consulting Service**
- **2015 India Lucknow MRT Project**
- **2017 Indonesia Jakarta~Surabaya F/S Service**
2. Performance of KRNA

2-5. Overseas Projects

Since 2004,

USA
- Consultancy Service for California HSR

Cameroon
- Railway feasibility study for railway construction
- Railway Master Plan

Sudan
- Railway Capacity Building Program

Nepal
- Feasibility study of mass rapid transit system in Kathmandu Valley
- Detailed survey and design of electrified railway line-Phase1 & Phase2
- Railway Capacity Building Program

India
- Technical consultancy of Indian HSR detailed design
- PM contract for Lucknow metro

China
- 16 Construction Supervision for Chinese HSR

Bangladesh
- Technical consultancy of signaling system modernization

Vietnam
- Engineering consultancy and training service for Vietnam Railway Modernization Projects

Indonesia
- PMC for Master Plan of JABOTAK railway circular line improvement
- System package project on Indonesia Jakarta LRT (Light Rail Transit) 1st phase
- Feasibility study on Jakarta LRT 2nd phase main project

Malaysia
- Technical consultancy of signaling system modernization

Malaysia-Singapore
- Malaysia-Singapore HSR Feasibility Study

Paraguay
- PMC for FS on the railway construction
- FS for construction of intercity railway
- Building Consultancy to select main contractor for light rail transit

Philippines
- Consultancy Services for the LRT line 2 east extension

Pakistan
- Railway Capacity Building Program

Pakistan
- Railway Capacity Building Program

Mexico
- Railway Capacity Building Program

Mexico
- Railway Capacity Building Program

Brazil
- Railway Capacity Building Program

Brazil
- Railway Capacity Building Program

USA
- Consultancy Service for California HSR
Introduction of Korean HSR

1. Definition of HSR
2. Background of HSR
3. Effects of HSR
4. Technical characteristics
5. Honam HSR - 400km/h Test-bed Track
3. Korean HSR

3-1. Definition of HSR

1. Definition
   - HSR: Over 200km/h (Now, 300km/h)

2. Construction
   - Government, Local Government, KRNA and SPC (Private Investor)

3. Financing
   - Gyeong-bu/Honam HSR: Gov. 50% KRNA 50%
   - Seoul Metropolitan HSR: Gov. 40% KRNA 60%
In 1990s, more than two thirds of population and GDP were concentrated in the Seoul-Busan corridor.

Insufficient transport facilities compared to massive logistics volume.

HSR was selected as the best alternative in terms of economic efficiency.
3. Korean HSR

3–3. Effect of HSR

- High construction cost, but Excellent transport efficiency

<table>
<thead>
<tr>
<th>Contents</th>
<th>HSR (A)</th>
<th>Highway (B)</th>
<th>Double Track (C)</th>
<th>A/B</th>
<th>A/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction cost</td>
<td>38.2bil won/km</td>
<td>26.2</td>
<td>25.0</td>
<td>1.46</td>
<td>1.53</td>
</tr>
<tr>
<td>Transport Capacity</td>
<td>520,000 /day</td>
<td>25</td>
<td>27.5</td>
<td>2.08</td>
<td>1.89</td>
</tr>
<tr>
<td>Operating time</td>
<td>1hr56min</td>
<td>5hr 20min</td>
<td>3hr 50min</td>
<td>△ 2.7</td>
<td>△ 1.98</td>
</tr>
<tr>
<td>Transport Efficiency</td>
<td>3.93</td>
<td>1</td>
<td>1.6</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

3. Korean HSR

3–3. Effect of HSR

Less CO2 emission, Great energy saving effect

→ **Reduction of environmental impacts and green growth**

<table>
<thead>
<tr>
<th>구분</th>
<th>KTX</th>
<th>CAR</th>
<th>Conventional train</th>
<th>BUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Emission (CO2/person·km)</td>
<td>26.9g (1)</td>
<td>168.2g (6.3 times)</td>
<td>66.4g (2.5 times)</td>
<td>55.7g (2.1 times)</td>
</tr>
<tr>
<td>Energy Consumption (kcal/person·km)</td>
<td>54.5 (1)</td>
<td>570.3 (10.47 times)</td>
<td>190.5 (3.5 times)</td>
<td>177.3 (3.26 times)</td>
</tr>
</tbody>
</table>

- Required land per unit transportation capacity is just 29% of Highway
  → **Promoting Efficient national development**
- Higher safety and timeliness than other transportation means
  → **Providing more convenient transportation services**
Safety enhancement at high speed

- **Safety Devices** Preventing train accidents, due to events such as natural disasters.
  - Detector for climate change (strong wind, snow, rainfall), obstacles and rockslides, dragging materials, temperature of train-axle and rail.
  - Turnout heater, Earthquake detector, and safety prevention systems.

High ride comfort

- Structures for Minimizing passengers’ ear discomfort.
- For smoother path, the rails welded together to form one continuous rail. (300m CWR)

Structure durability

- Providing structures for less deflection and vibration while driving on the Bridges and durable at the event of earthquake.
- Reinforced track-bed to be designed to be stiff enough in supporting a track.
- Approach block between a fill section and a structure to prevent unequal settlement (or deformation).
3. Korean HSR

3–4. Technical characteristics (Driving Safety)

Korea’s HSR System
Safety is the core value of our system. Our safety system is to detect and remove any risks in advance, ensuring safe operation includes maintenance.

Centralized Traffic Control (CTC)
Safety Devices

Korea is proud of its advanced train control system, called the Korea Train Control System (KTCS), using the 6G generation wireless communications technology.

CTCBuilding

LTE-M in 5G is capable of providing high-quality telecommunications services such as long-distance and video services with localized centralized control and assurance and ground mobile communication.

Korea is proud of its advanced train control system, called the Korea Train Control System (KTCS), using the 6G generation wireless communications technology.

Technical Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max speed</td>
<td>300 km/h</td>
</tr>
<tr>
<td>Formation</td>
<td>8 cars/300km/h</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0-300 km/h in 4.1 seconds</td>
</tr>
<tr>
<td>Grade</td>
<td>15% climbing</td>
</tr>
<tr>
<td>Capacity</td>
<td>500 passengers</td>
</tr>
<tr>
<td>Electric Power</td>
<td>25 KV AC, 50 Hz</td>
</tr>
<tr>
<td>Track gauge &amp; Type</td>
<td>1,435mm, Standard gauge</td>
</tr>
</tbody>
</table>
Minimize air pressure variation, and accordingly minimize ear discomfort when train enter tunnel with high speed.

- Tunnel design reflecting air flow, to minimize tunnel section flow effects. *situation*
3. Korean HSR

3-4. Technical characteristics (Structural stability)

- Stability of a bridge structure with less deflection and vibration, and also earthquake resistant system while high-speed train’s driving.
- Concrete strength 400kg/㎡, Box shaped superstructure, Seismic design etc
3. Korean HSR

3–4. Technical characteristics (Structural stability)

**Reinforced track bed**
- Increasing bearing capacity of track bed to be stiff enough in supporting a track.

<table>
<thead>
<tr>
<th>Trackbed shape</th>
<th>Bearing capacity of track bed</th>
<th>Reinforced trackbed (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sub-ballast</td>
<td>Graded crushed stone</td>
</tr>
<tr>
<td>Banking</td>
<td>K30 ≥ 11 kg/cm³</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>7 kg/cm³ ≤ K30 &lt; 11 kg/cm³</td>
<td>20</td>
</tr>
<tr>
<td>Cutting</td>
<td>K30 ≥ 11 kg/cm³</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>7 kg/cm³ ≤ K30 &lt; 11 kg/cm³</td>
<td>20</td>
</tr>
</tbody>
</table>

**Approach block**
- Transition zone with certain length of 3% cement mixed gravel and graded crushed stone to prevent differential settlement in soil and bridge connected section.
Establish test-bed track for design speed 400km/h in some part of Hanam HSR line for commercializing next generation of HSR(HEMU-430, Max. speed 430km/h)

* [Southbound] Gongju→Iksan(28km), [Northbound] Jeongueb→Iksan (28km)
04 Introduction of Speed up project

1. Speed up plan of the conventional line
2. Investment strategy and Benefit Cost analysis
3. Fundamental Technology for Speed up
4. Speed up case: Jeolla line
4. Introduction of speed up project

4-1. Speed up plan of the conventional line

**Purpose of Speed up**
- Balanced regional development & Improved transport share
- Green growth through speed up on existing line

**Project contents**
- Speed up on existing line
  - Train operating speed: 180km/h~200km/h and over
  - Within 2~3 hours of travel time between metropolis

**Background**
- Just adding about 5 % of construction costs can speed up from 150km/h speed to 230km/h during construction stage
4. Introduction of speed up project

4-1. Speed up plan of the conventional line

**Target**
- For commuter: Reduce commute time
- For Operator: Increase in revenue, decrease in operating costs
- For Society: Decrease in car accidents & environmental expense

**Review**
- Rolling stocks: EMU(180, 200, 230km/h), KTX II etc.
- Operation method: slow train → express
- Train speed limit: Keep or Relax
### 4. Introduction of speed up project

#### 4-2. Investment strategy and benefit cost analysis

<table>
<thead>
<tr>
<th><strong>Speed up on existing line</strong></th>
<th><strong>Shortening</strong></th>
<th><strong>Improving driving speed</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Target route that will be reduced</td>
<td>① Improve maximum speed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>② Improve curving performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>③ Improve turnout passing speed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>④ Improve limited speed</td>
<td></td>
</tr>
<tr>
<td><strong>Reducing time loss</strong></td>
<td>Reducing dwell time, Widening door, Direct Train, automatic door etc.</td>
<td></td>
</tr>
</tbody>
</table>
4. Introduction of speed up project

4–2. Investment strategy and benefit cost analysis

Benefits & Costs
→ Depend on: 1. Feature of targeted route
   2. Way of speed-up

Classification of ways of Speed-up by level of costs

<table>
<thead>
<tr>
<th>Level</th>
<th>Station improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Level</td>
<td>Station improvement</td>
</tr>
<tr>
<td>Medium Level</td>
<td>Up-Lifting Cant, Extension of Transition curve, Turnout Improvement, Strength of Track, Catenary Improvement, Signaling system Improvement, Rolling Stock Improvement, New Rolling Stock Purchase</td>
</tr>
<tr>
<td>High Level</td>
<td>Electrification, Bridge &amp; Tunnel Reinforcement, Extension of Radius of Curve, New Line, Double-Tracking</td>
</tr>
</tbody>
</table>
Technology for track system and interface improvement

- Consider the linear suitability of rolling stock on existing line

<table>
<thead>
<tr>
<th>Review List</th>
<th>Study Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum radius of curve</td>
<td>- Estimate maximum passing speed of rolling stock on minimum radius of curve</td>
</tr>
<tr>
<td></td>
<td>- Review the radius of curve to achieve target passage speed</td>
</tr>
<tr>
<td>Length of transition curve</td>
<td>- Review the suitability of transition curve in response to speed up</td>
</tr>
<tr>
<td></td>
<td>- Study on the extension of transition curve</td>
</tr>
<tr>
<td>Cant</td>
<td>- Cant improvement effect by upgraded rolling stock</td>
</tr>
<tr>
<td></td>
<td>- Review the current cant speed to achieve target passage speed</td>
</tr>
<tr>
<td></td>
<td>- Review the cant deficiency and excess considering the velocity of low speed(freight) and high speed rolling stock</td>
</tr>
<tr>
<td>Straight length between Curve</td>
<td>- Review the adequacy when driving at target speed</td>
</tr>
</tbody>
</table>
4. Introduction of speed up project

4–3. Fundamental Technology for Speed up

Case: Draft speed-up strategy according to Linear condition and Demand
4. Introduction of speed up project

4-4. Speed up Case : Jeolla line

Summary

Speed up on existing Line (Jeolla Line) : Ik-san ~ Yeosu (180.3km) with speed of 230km/h for better traffic convenience of local residents
### Details

<table>
<thead>
<tr>
<th>Field</th>
<th>Budget (Hundred Million Won)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signaling</td>
<td>377</td>
<td>ATP Ground Segment &amp; Installation of Safety Equipment</td>
</tr>
<tr>
<td>Track</td>
<td>264</td>
<td>Weighting Track &amp; Turnout Improvement</td>
</tr>
<tr>
<td>trackbed</td>
<td>236</td>
<td>Structure Repair and Rehabilitation &amp; Installation of Safety Fences</td>
</tr>
<tr>
<td>Electricity</td>
<td>57</td>
<td>Adjustment on Catenary &amp; Installation of Power Supply Equipment</td>
</tr>
</tbody>
</table>
4. Introduction of speed up project

**Signaling**

- **ATP Ground Segment Equipment (Balise 1,720, Lineside Electronic Unit 308) Installation**
  - Compact Balise Controlled: Sending revealed information of ground signal to ATP Evaluation Unit
  - Compact Balise Fixed: Sending tracks and geographical information to ATP Evaluation Unit
  - Lineside Electronic Unit (L.E.U): Sending information of ground signal to Balise

*LEU*: Lineside Electronic Unit
4. Introduction of speed up project

4–4. Speed up Case : Jeolla line

**Track**

- **Details**
  - Turnout Change : elastic → swing nose
  - **Weighting Track** (50→60kg) : 26.5km
  - Uplifting track & Adjustment of Cant : 37.9km

<table>
<thead>
<tr>
<th>Present condition</th>
<th>Under Construction</th>
<th>Speed-up</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Present condition" /></td>
<td><img src="image2.jpg" alt="Under Construction" /></td>
<td><img src="image3.jpg" alt="Speed-up" /></td>
</tr>
</tbody>
</table>
4. Introduction of speed up project

4–4. Speed up Case : Jeolla line

Details
- Repair and Rehabilitation for Deteriorated Bridge Structure & Abrasion (Expansion joint on bridges(5,782m), Bridge Bearing(946), Bridge Deck(9,084 m²) etc)
- Installation of Safety Fences for neighboring residents and animals

<table>
<thead>
<tr>
<th>Present Condition</th>
<th>Change of Bridge bearing</th>
<th>Repairing Bridge deck</th>
<th>Repairing Expansion Joint on bridges</th>
</tr>
</thead>
</table>

- Speed-up

Images of current and improved conditions are shown in the table.
4. Introduction of speed up project

4-4. Speed up Case : Jeolla line

Electricity

Details
- Catenary : Adjustments on Height, Deviation and Inclination etc (289.5km)
- Power : Installation of Power supply for Snow melting equipment for railway turnout

<table>
<thead>
<tr>
<th>Catenary Height Gap</th>
<th>Construction</th>
<th>Present Standard</th>
<th>Speed up Standard</th>
<th>note</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5,200~5,400㎜</td>
<td>Height gap between neighboring line ±30㎜</td>
<td>○ The more the gap, the more the degradation damage of catenary and pantograph due to arc discharge</td>
</tr>
</tbody>
</table>
4. Introduction of speed up project

4-4. Speed up Case : Jeolla line

**Electricity**

- Adjustments on Catenary for speed-up

<table>
<thead>
<tr>
<th>Pre-Sag</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Pre-Sag Image" /></td>
<td><img src="image2.png" alt="Height Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Deviation Image" /></td>
<td><img src="image4.png" alt="Deviation Image" /></td>
</tr>
</tbody>
</table>
Muchas Gracias!