



IRSC 2025

***Advancing Railway Safety through
Innovations and Collaborations***

Hong Kong, China 25th - 30th November 2025

Development Technology to Analyze, Evaluate, and Prevent Human Errors of Railroad Workers

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Project Overview

Project Name

Development of technology for analysis, evaluation, and prevention of human errors by railway worker

Research Period

April 2023 ~ December 2027

- Development of a railway worker human error analysis·evaluation·prevention system to reduce accidents caused by human error of railway workers
- “Factors causing human error (e.g. fatigue, time pressure)
→ Human error (e.g., inadequate situation judgment/response) → Accident”
- From the beginning of the process, analyze and evaluate human factor data to ultimately reduce accidents

Detect hazards

R

Recognise
the hazards

Share risk information

I

Inform
others

Take preemptive action

S

Solve the
problem

Prevention and management

K

Know how
to improve



Sub-theme: Risk Control and Management

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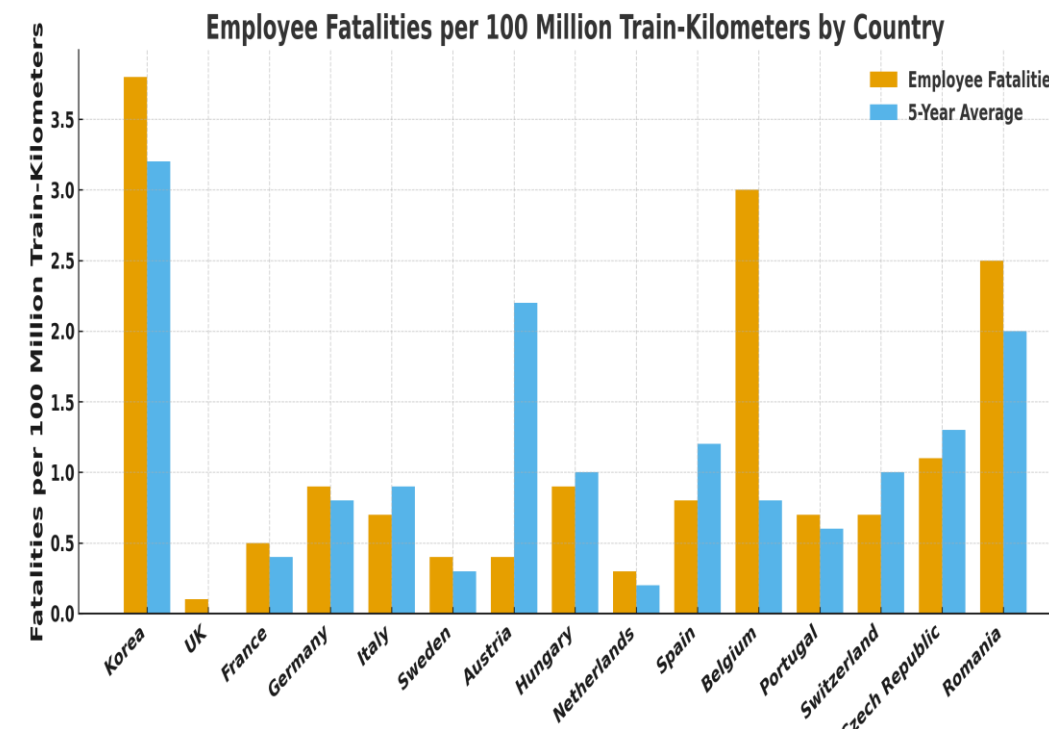
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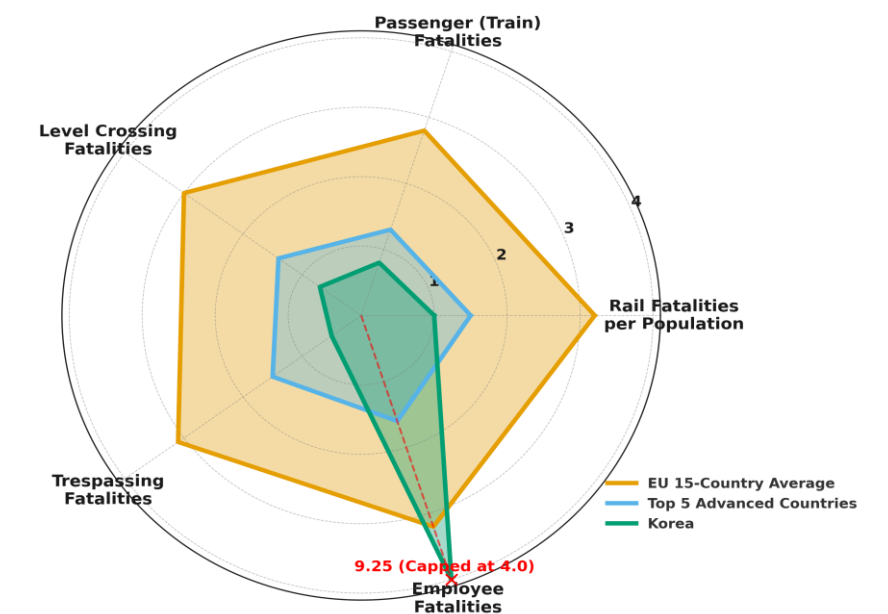
Human Error Statistics

Continued occurrence of railway accidents due to human factors of railway workers

- Train collisions, derailments, fires, and other train accidents are caused by human errors of railway personnel such as train operators, and controllers, accounting for 47%.
 - Train accident factors : facility·vehicle factors 51%, human factors 47%, external factors 2%
- The incidence rate of casualties among railway workers is more than 5 times higher than in developed countries, with a recent increase in worker fatalities
 - Number of worker fatalities per 100 million KM by country(persons, 5-year average): South Korea 3.8, Germany 0.9, France 0.4, United Kingdom 0



Comparison of Railway Fatalities by Category (Population-Normalized)



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Accident Cases & Problem Definition

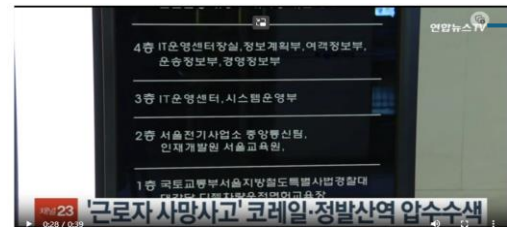
Inadequate prevention and management of human factors of railway workers



**SRT Derailment
Accident('22.7)**



**Obong Station Fatality
Accident (Nov. '22)**



**Jeongbalsan Station
Fatality Accident (Oct. '22)**

- Recently, serious damage has occurred due to derailments and worker casualties caused by human errors of workers
 - Despite the continuous occurrence of abnormal signs such as persistent track misalignment in the accident section of the rail, maintenance measures such as rail resetting were not implemented
 - When the preceding train passed through the accident section, it reported abnormal vibrations, but the control center did not immediately inform the following train of the fact, causing the accident.
 - The transportation officer conducted signaling to the engineer without checking the shunting route.
 - During the shunting, the engineer did not comply with the signal, resulting in a pinching accident involving the shunting worker.
 - A track worker was involved in an accident while working outside the designated time to complete the work

「Industrial Safety and Health Act」 Worker Safety Enhancement(Effective as of `20.1),
Introduction of 「Serious Accident Punishment Act」 (Effective as of `22.1) etc. Increasing social
demand for worker safety, urgent need for improvement



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Vision and Objectives of the Project

Vision	Implementation of a systematic and scientific safety management focused on prevention for railway workers		
Objective/Goal	Objective: Prevent accidents and failures caused by human error in railway workers by using analysis, evaluation, and prediction technologies for human error, and strengthen the emergency response capability during unusual situations Goal: Contribute to government policy to reduce accidents caused by human error among railway workers by 50%		
Key Tasks	Development of a system to collect and analyze human factor data for railway workers and support operating and on-site safety	Development of an integrated system for analysis, prediction, and management of human error influence factors for railway workers based on evaluation	Development of a user-interactive integrated virtual training system for response to abnormal situations by linking with human error analysis, prediction, and management systems for railway workers

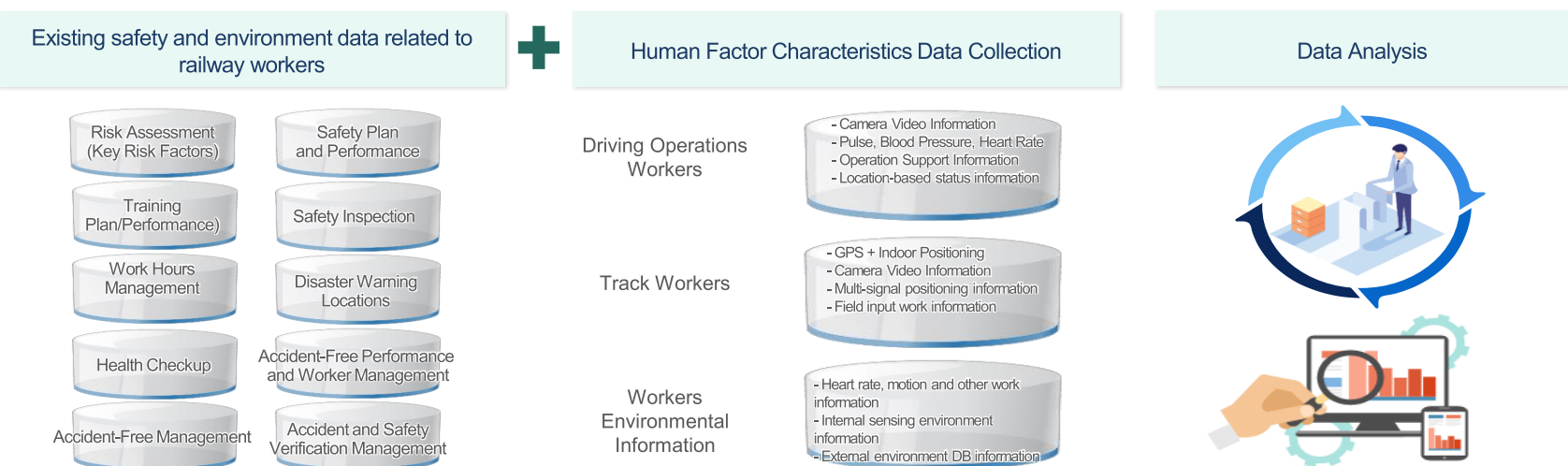
Performance Indicators	Human factor data collection·management system Accident·Incident Coverage (%) 90% Achieved	Job analysis and human error evaluation software Human Error Mechanism Modeling (%) 90% Achieved	Full Type joint virtual training for early response to unusual situations 10+ simultaneous trainees
	Real-time integrated field safety management system for track workers Contribution to Track Worker Accident Reduction(%) 50% Achieved	Cyber-Physical System (CPS) based Human Error Prediction SW Human Error Prediction Accuracy(%) 50% Achieved	Light Type joint virtual training for early response to unusual situations 10+ simultaneous trainees
	Field job suitability evaluation system Measurement Accuracy(%) 90% Achieved	Risk-based railway worker work management system Management Suitability(%) 90% Achieved	Real-time comprehensive analysis software based on trainee's biometric signals Real-time comprehensive analysis software for training effectiveness Diagnostic Suitability(%) 90% Achieved



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System Overview

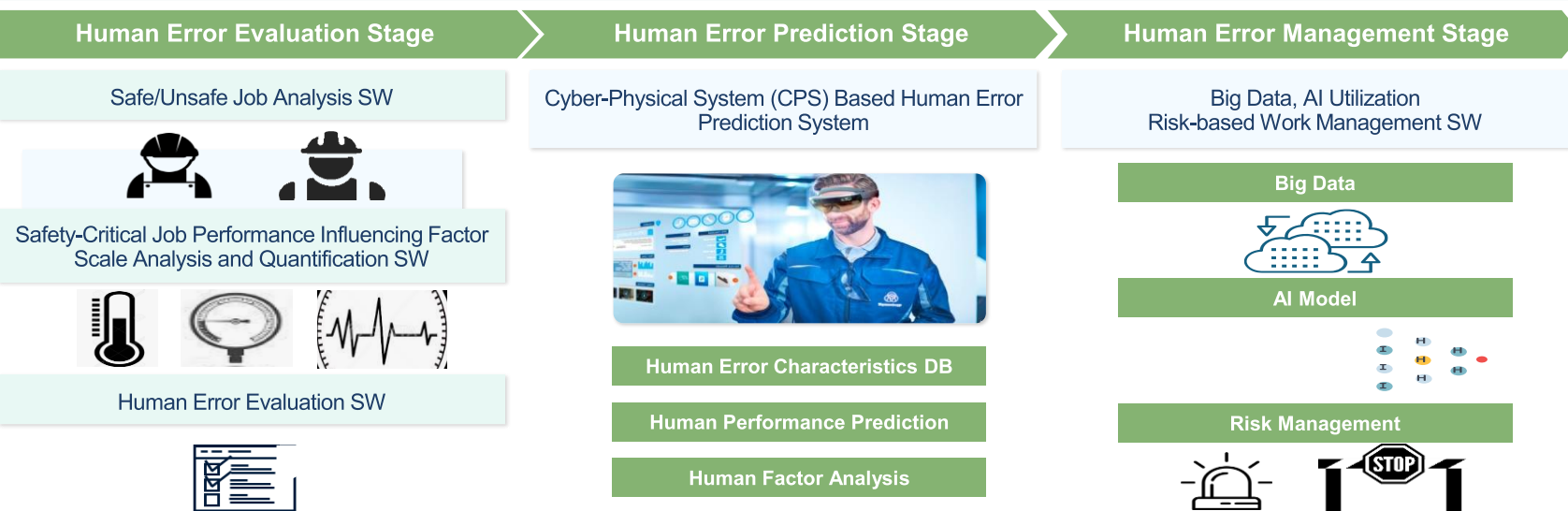
Railway worker human factor characteristics data collection and analysis system



Railway Worker Operation Safety Support System



Railway Worker Human Error Evaluation/Prediction Integrated Management System (SW)



Multi-railway worker joint virtual training system for responding to unusual situations



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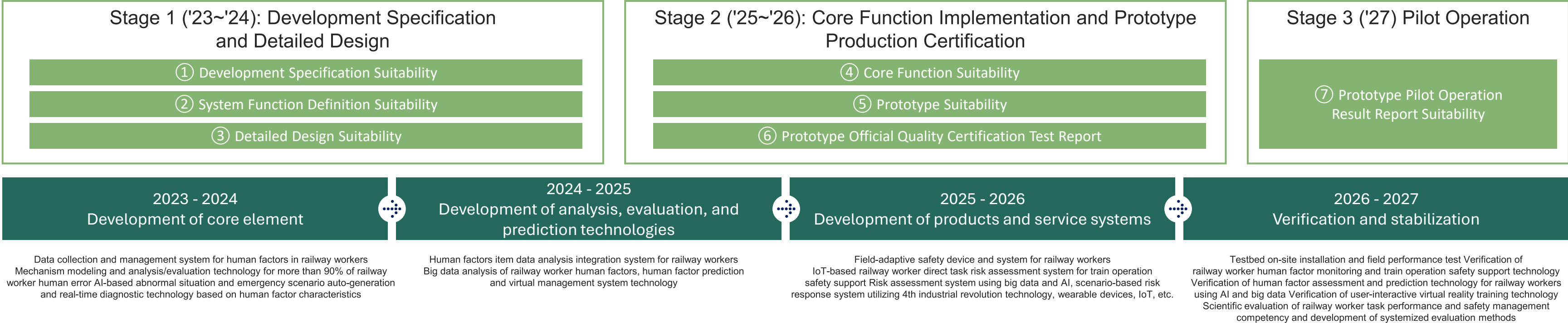
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R&D Framework

Basic Performance Indicators and Research Plan Establishment

- To ensure that research outcomes can be applied in real-world settings, establish research plans for prototype development and certification, and field application.
- Establish research plans with basic 3 stages (①Development Specifications and Detailed Design, ②Core Function Implementation and Prototype Production Certification, ③Pilot Operation) and detailed 7 stages of performance indicators, and conduct research by establishing additional performance indicators if necessary



- Transportation Safety Authority, KORAIL, Korea Rail Network Authority, and Busan Transportation Corporation, planning and conducting research to appropriately reflect policies,



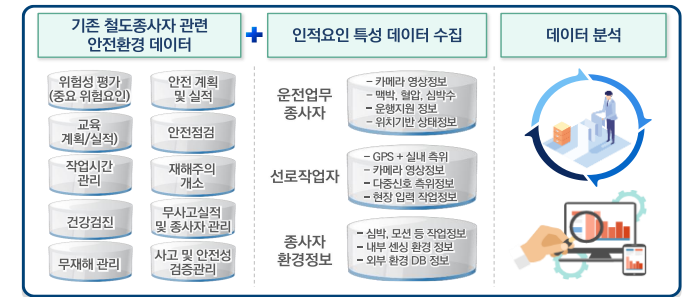
Sub-theme: Risk Control and Management

Railway Personnel Human Factors Data Collection·Analysis System

Railway Worker Human Factor Characteristics Data Collection and Analysis System

Purpose

Integrated collection/analysis/management of human factor characteristic data, such as precursor factors for human error among railway workers, and background factors, and securing human error pre-detection technology.



AS-IS

- Analysis of Human Errors in Railway Workers: Inadequate Human Factors Characteristics Data Collection·Management
- Lack of technology that can detect human errors in advance by detecting abnormal conditions·incorrect habits, etc. of railway workers

Railway Worker Human Factors Data Collection and Management System Development

Real-time Data Collection and Measurement Device Development for Railway Workers' Human Factors Characteristics

Research Task

- Development of Standard Data Items and Collection Cycle/Scale Considering Railway Personnel Risk Factors and Human Factor Characteristics
- Development of Railway Personnel Human Factor Characteristics Data Collection, Measurement, and Management System
- Development of a device to collect and measure real-time human factor characteristic data of railway workers (location, voice, video, biometric signals, etc.)
- Development of devices for collecting and measuring real-time human factor characteristics data (location, voice, video, biosignals, etc.) of track workers on operating lines (including train formation workers)
- Development of a device for collecting and measuring on-site job suitability data for railway workers

TO-BE

- Establishment of a system for collecting·managing human factor characteristic data, with over 90% coverage of accidents due to human error·incidents
- AI based real-time human factors monitoring system field deployment and operation



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Railway Worker Human Factors Data Collection-Management System

Railway Worker Human Factor Characteristics Data Collection and Analysis System

Integration of NEW and EXISTING Safety Data for Railway framework for human-factor risk intelligence

NEW DATA

- AI Cameras
- Physiological Sensors
- Biometric Signals

EXISTING DATA

- Training Records
- Risk Assessment
- Health Checks

Human Factor Integration & Management

Prediction SW
(Human Error Assessment)

Virtual Training System
(Response to Unusual Situations)



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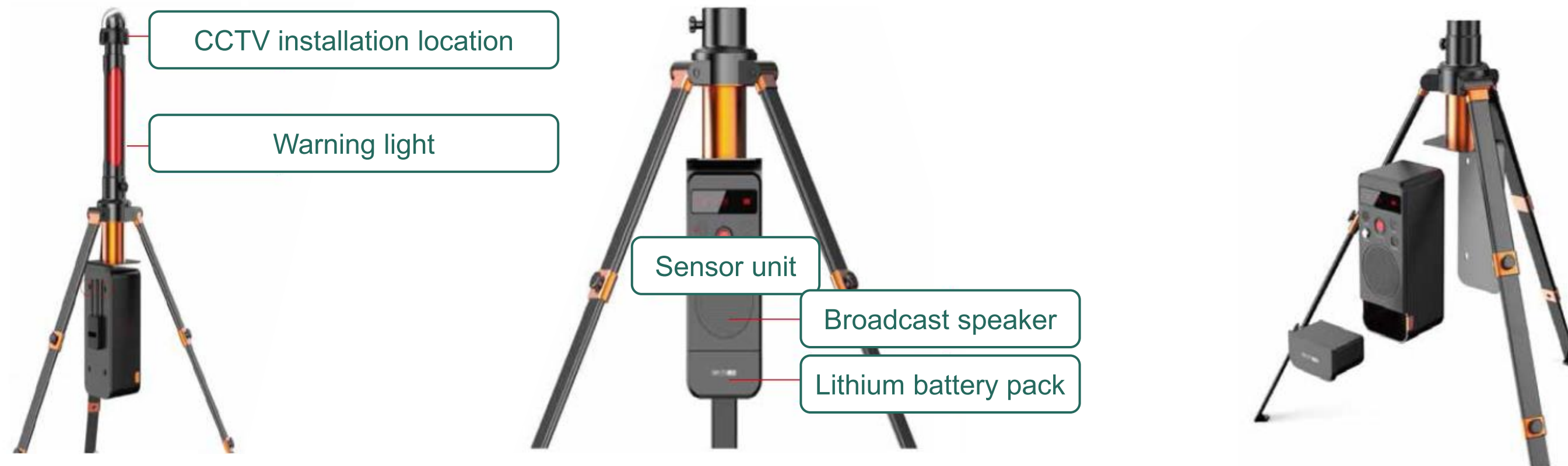
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Railway Worker Human Factors Data Collection-Management System

Real-time human factor characteristic data (location, voice, video, biometric signals, etc.) collection and measurement device of workers on operating lines (including train formation workers)

- Detailed design of a mobile CCTV capable of collecting and measuring the work situation and real-time human factor characteristic data of track workers on operational lines
- Beacon lights and speakers capable of indicating work status and alarms, equipped with various sensors and communication equipment for communication functions.
- AI object recognition cameras are installed, allowing for real-time detection of unusual situations on site(such as worker falls, facility collapses, etc.)



Railway Worker Human Factors Data Collection-Management System

Railway Workers' Field Job Suitability Data Collection and Measurement Device

- Detailed design of a device for collecting and measuring job suitability data before and after field deployment of railway workers
- Designed as a contactless Through Gate type to enable identity verification, attendance checks, and biometric information collection.
- The collected biometric information is designed to enable decision-making on work deployment through the AI module, and is designed for easy installation and mobility both indoors and outdoors.

- Entry
- Attendance (Entry) check
- Fever measurement
- Facial recognition, biometric measurement (5 sec)
- Alcohol measurement (3 sec)
- Display measurement result
- Entry (YES/NO)
- Task execution



- 1/ Entry (Tag)
2. Fever/biometric/alcohol measurement
3. Measurement value → result
4. First AI determination: entry (YES/NO)

YES



5. Task execution

NO



6. Detailed check



Detailed check personnel



Final AI decision: enter work or denied



※ Alcohol measurement required workers vs. alcohol measurement exempt workers — two types of gate to be developed



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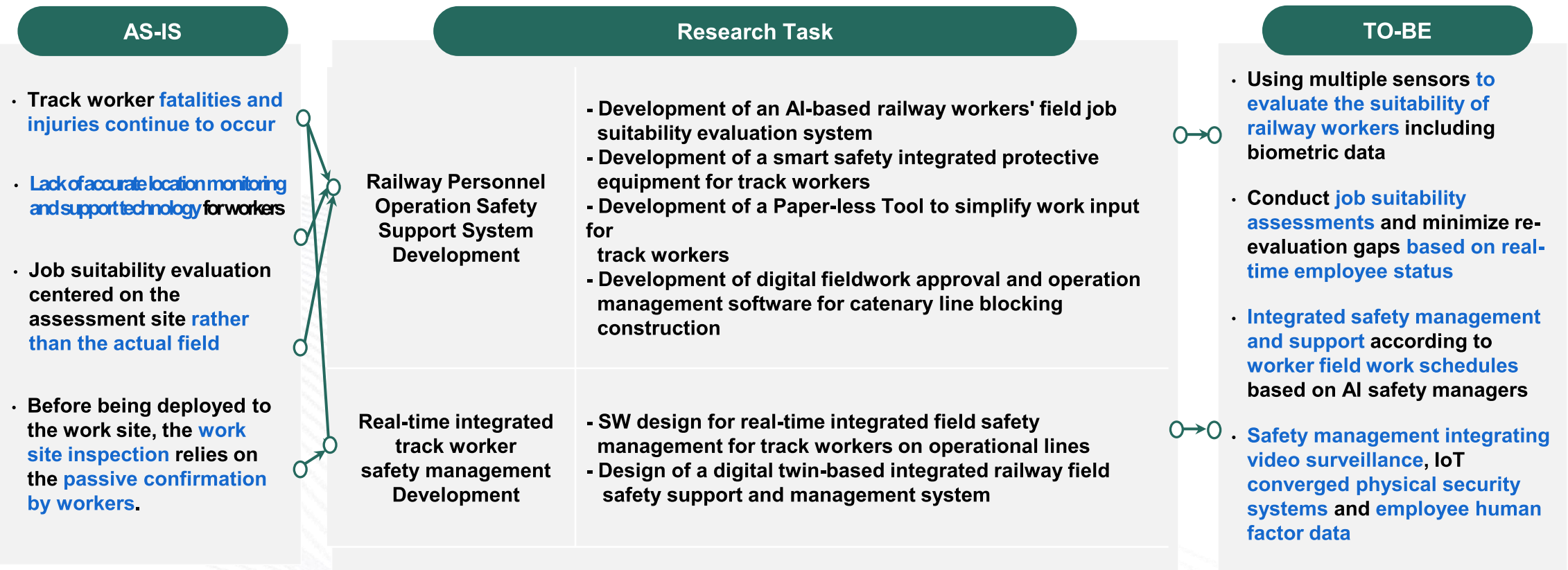


Railway Worker Human Factors Data Collection·Management System

Railway Worker Operation Safety Support System

Purpose

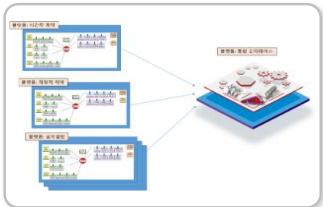
Establishment of a digital twin-based railway worker real-time integrated field operational safety support and job suitability assessment system



Smart wearable safety equipment for standard main line railway workers

Integrated real-time on-site safety management system for railway workers

AI-based software for evaluating field job suitability of railway workers



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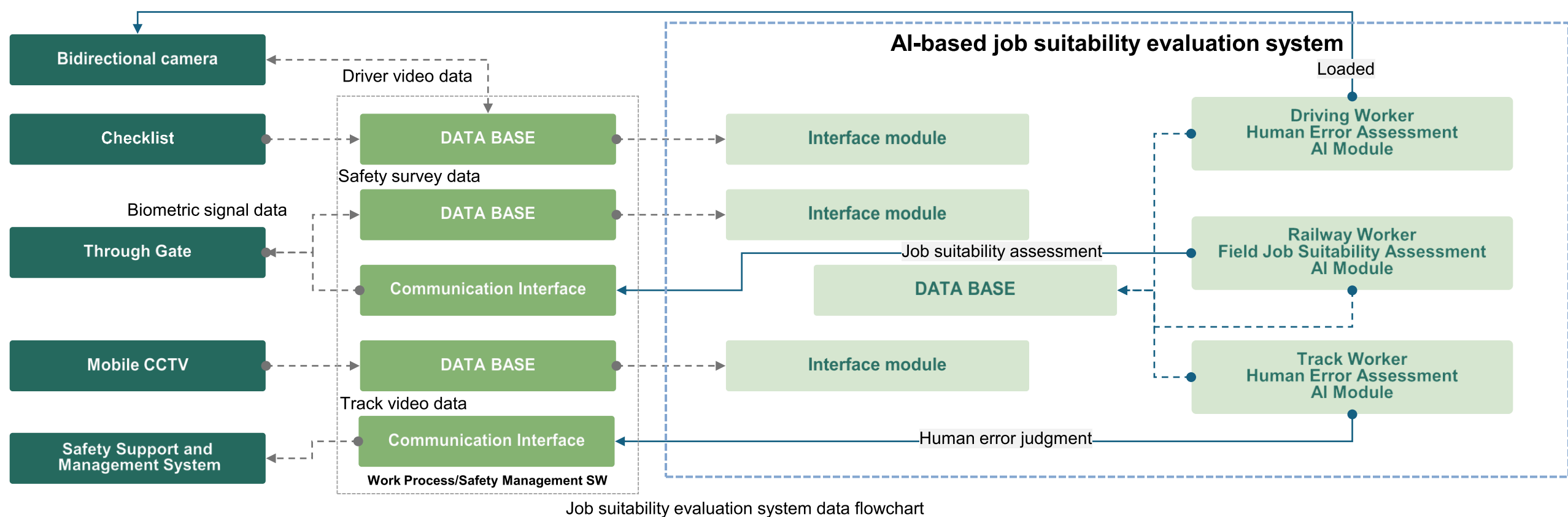
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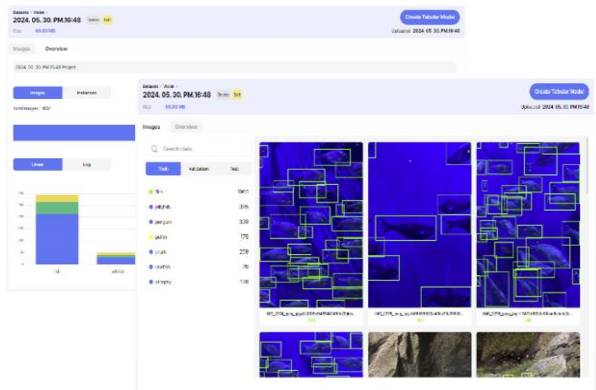
Railway Worker Operation Safety Support System

AI-based railway worker field job suitability evaluation system

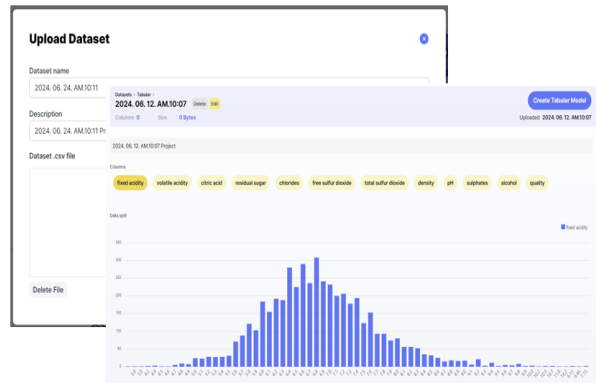
- Data learning through the developed data collection device and video analysis within the alarm device to develop an algorithm for real-time field job suitability assessment and abnormal behavior detection.
- Learning vision data and structured data respectively, writing an algorithm (MLOps) to present real-time abnormality status and designing detailed functions



Job suitability evaluation system data flowchart



Vision Data Result Screen



Structured Data Result Screen



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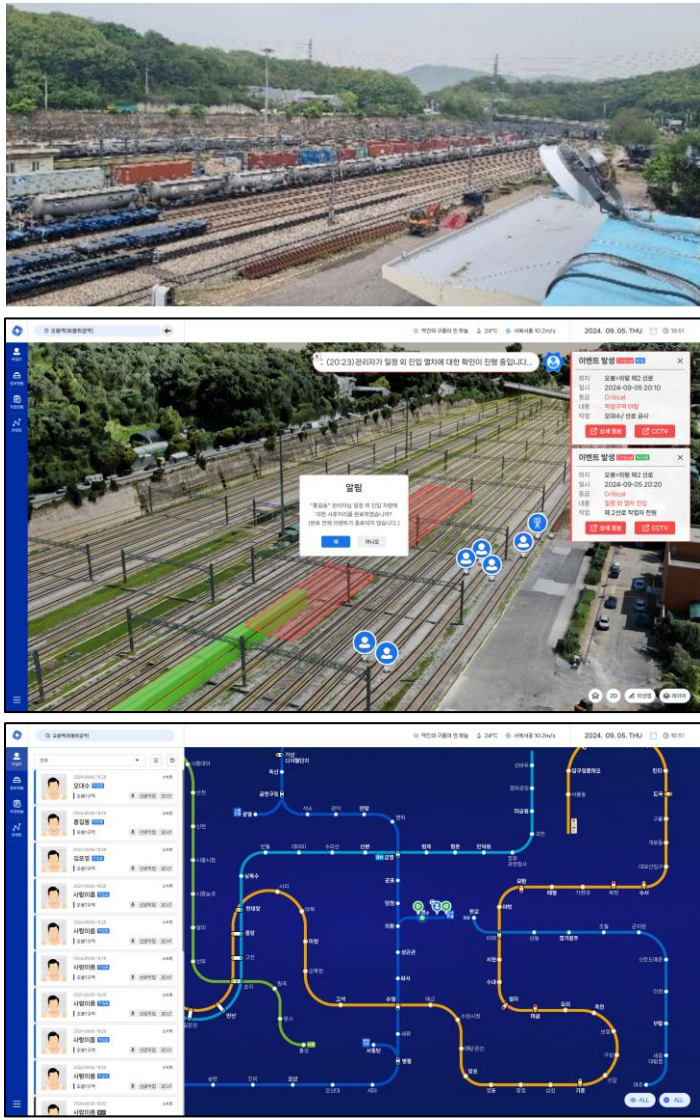
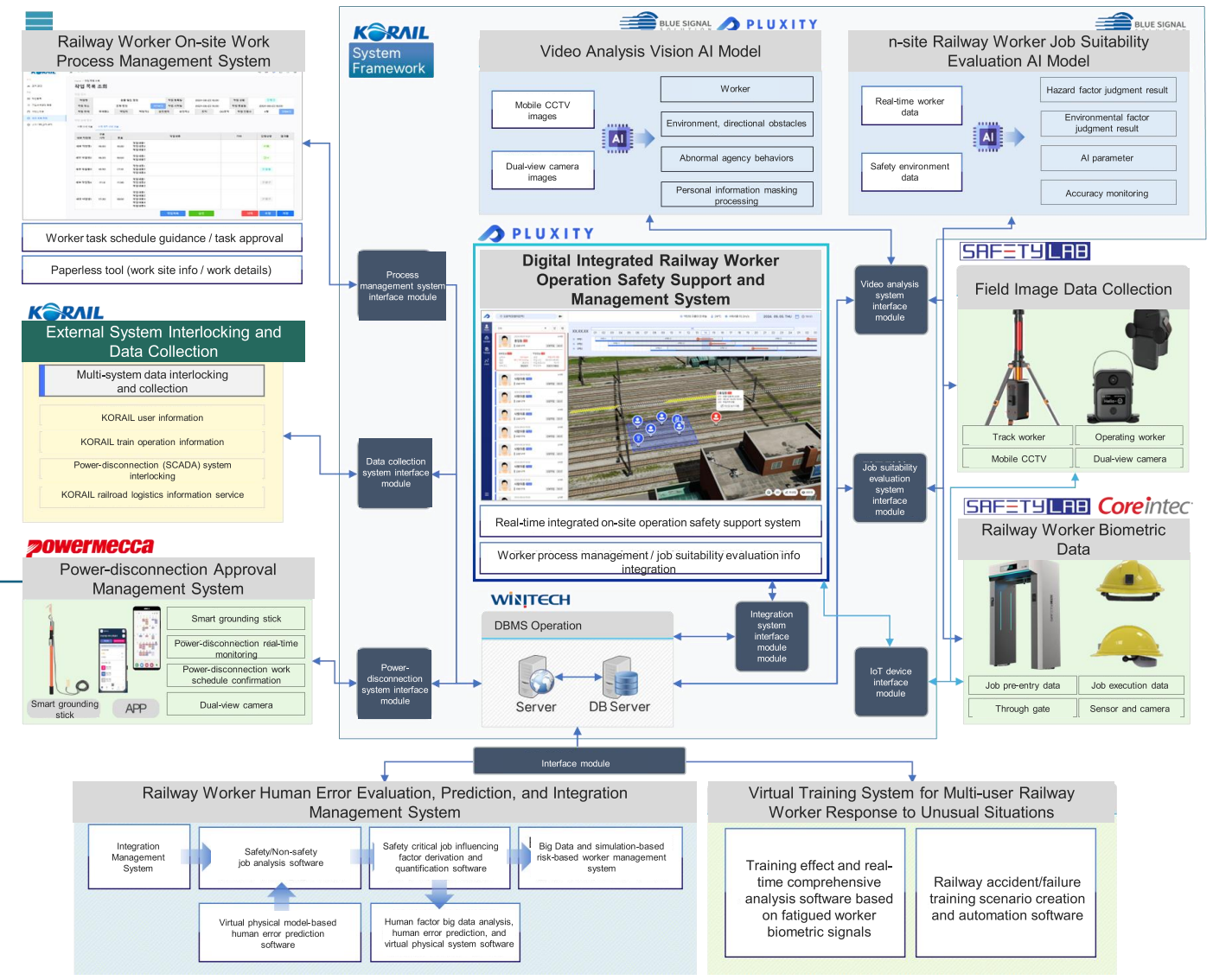
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Railway Worker Operation Safety Support System

Digital twin-based integrated railway field safety support and management system

- Design and development of a digital twin-based integrated railway field safety support and management system
- Currently, modeling has been conducted for the demonstration site, Obong Station, and additionally, detailed functions such as a simplified information screen that can display detailed information on trains and workers within the route map have been designed.



Sub-theme: Risk Control and Management

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Railway Personnel Human Error Evaluation-Prediction Integrated Management System

Railway Worker Human Error Evaluation/Prediction Integrated Management System (SW)

Purpose

Using the human factors characteristic data of railway workers, develop a human error evaluation model and secure technology for integrated management of human error evaluation/prediction.

AS-IS

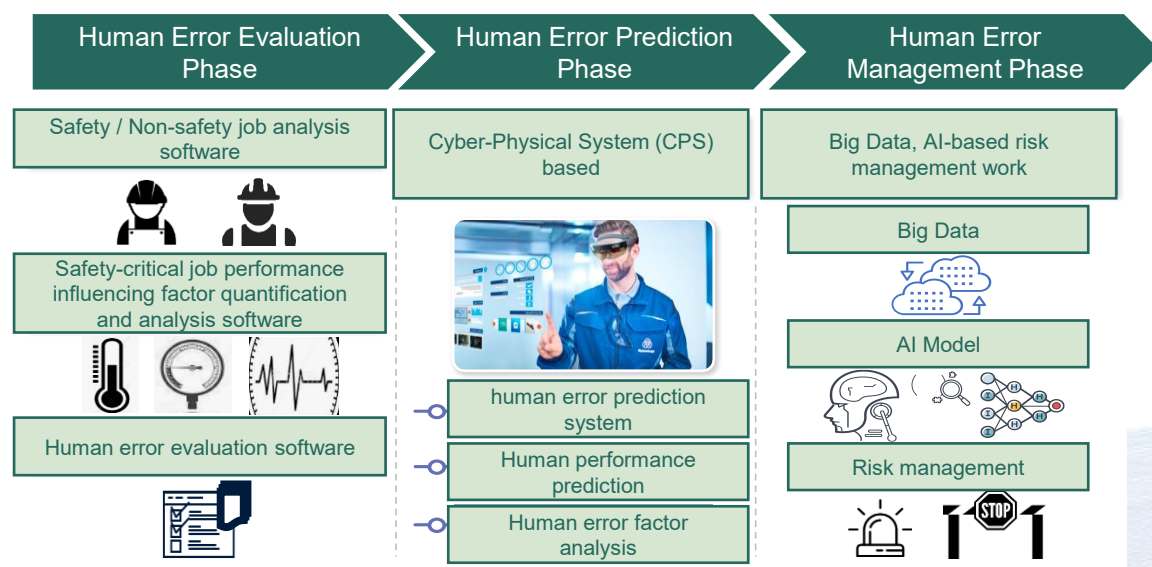
- Lack of consideration for human error in risk management.
- Lack of systematic management of human error
- Approximately 47% of railway accidents are due to insufficient systematic response to human error.

Research Task

- | | |
|---|--|
| Development of a system for analyzing railway worker tasks and quantifying influencing factors | - Development of methods for analyzing and quantifying worker task performance
- Development of SW for analyzing worker safety and non-safety tasks
- Development of SW for analyzing and quantifying influencing factors of essential safety task performance |
| Development of an integrated data analysis and human error evaluation system for human factors | - Development of an information promotion plan for evaluating worker human factors and human error
- Development of SW for evaluating worker human error |
| Big Data Analysis of Human Factors for Workers, Prediction of Human Error, and Development of Cyber-Physical System (CPS) | - Development of human error prediction SW based on worker cyber-physical system
- Big data analysis of human factors for workers, prediction of human error, and development of Cyber-Physical System (CPS)
- Development of AI-based risk-based worker task management system |
| Institutionalization of scientific evaluation and inspection system for work performance and safety management capabilities | - Establishment of measures for improving the inspection-related system for work performance and safety management capabilities
- Development of human factor evaluation and inspection procedures and guidelines for workers
- Development of a standard classification system for human factors related to near-miss reports |

TO-BE

- Establishment of a systematic, comprehensive, and scientific management system for human error
- Conduct a risk assessment for human error to establish mid- to long-term safety measures.
- Establishment of short-term safety measures at the site based on the prediction/management of human error by workers



Sub-theme: Risk Control and Management

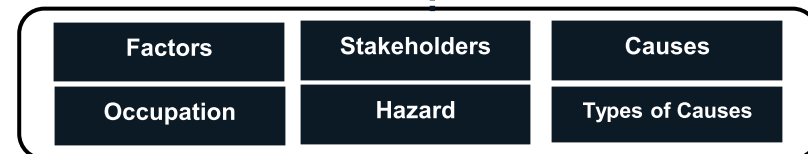
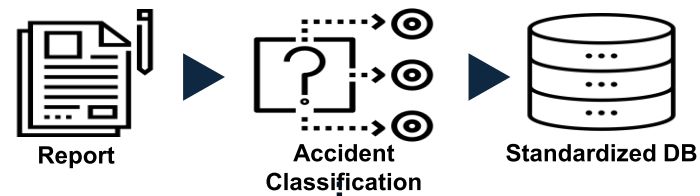
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Railway Personnel Human Error Evaluation-Prediction Integrated Management System

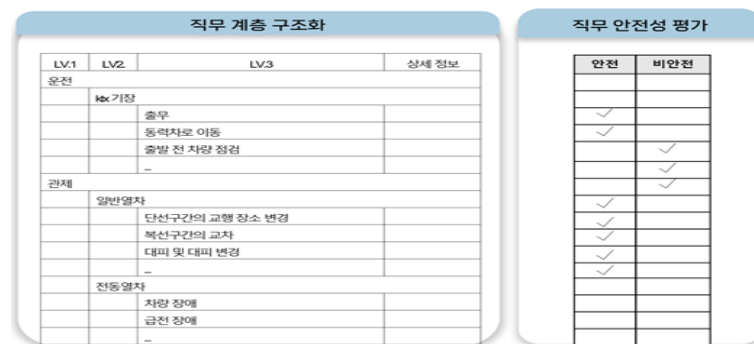
Worker job analysis

Standardization of actual accident DB



- ✓ Data collection of 240 actual accident cases
- ✓ Accident DB standardization and classification

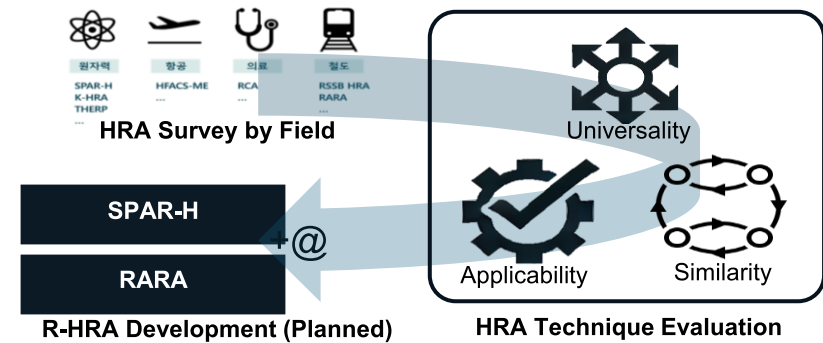
Accident data analysis & job classification



- ✓ FMEA, FT, ET based data analysis
- ✓ Safe/Unsafe Job Classification By Job Type
- ✓ Basic scale for error mechanism analysis

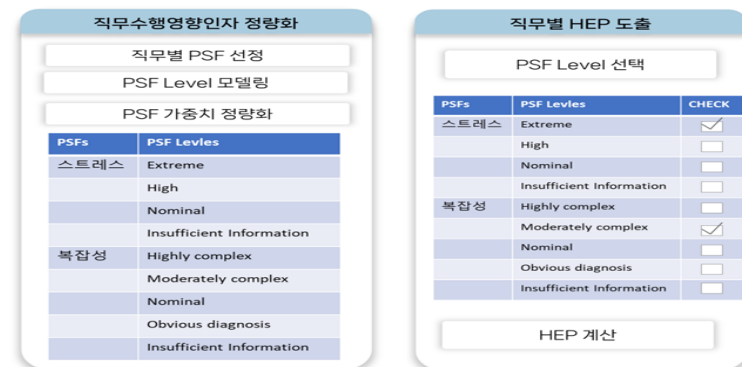
Quantification of influencing factors

Review of Human Reliability Analysis (HRA) techniques



- ✓ Preliminary Investigation of Similar HRA Techniques
- ✓ Merging PSF Aitems in HRA
- ✓ Railway-Specialized R-HRA Technique Basic Design

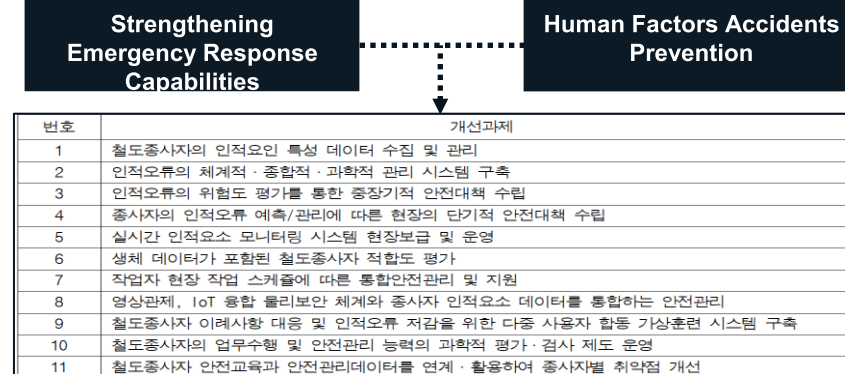
Quantification of Performance Shaping Factors (PSF)



- ✓ PSF Analysis/Quantification SW Function Definition
- ✓ Function Definition for Setting PSF Relationships by Job Type
- ✓ HEP Calculation Algorithm Function Definition

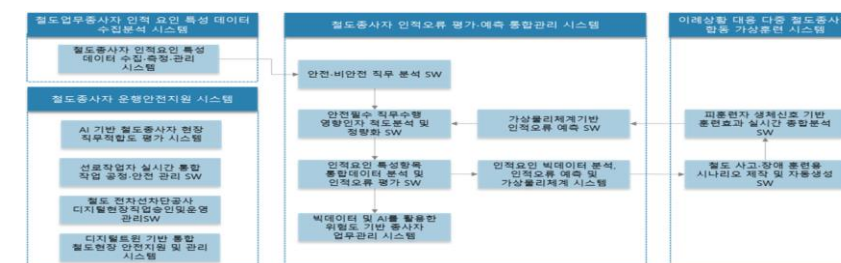
Integrated Strategy for SW Development

Derivation of Improvement Tasks



- ✓ Definition of 10 improvement tasks for the prevention of human error and enhancement of emergency response capabilities

Human Error SW System Configuration Diagram

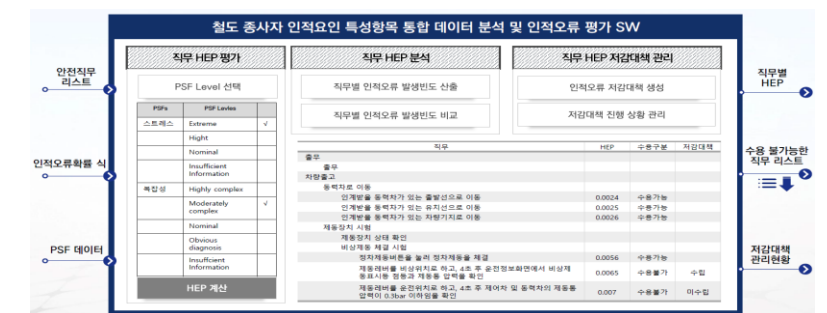


- ✓ Definition of workflow between human error SW
- ✓ Detailed SW System Definition

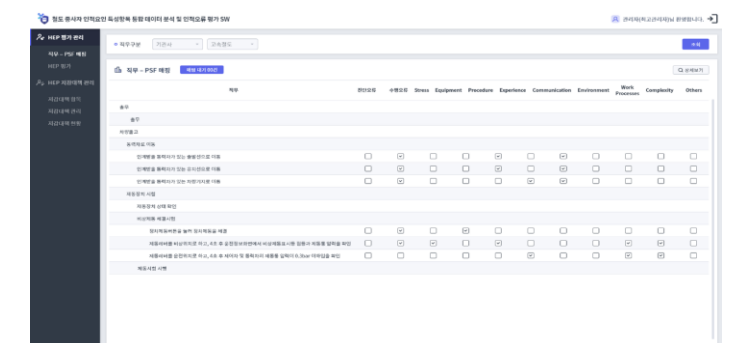
Integrated SW

Human factor characteristic items

Integrated data analysis and Human Error Evaluation SW



- ✓ Module architecture design
- ✓ Database detailed design



- ✓ PSF mapping/management function definition
- ✓ HEP evaluation definition
- ✓ Human error reduction measure management definition



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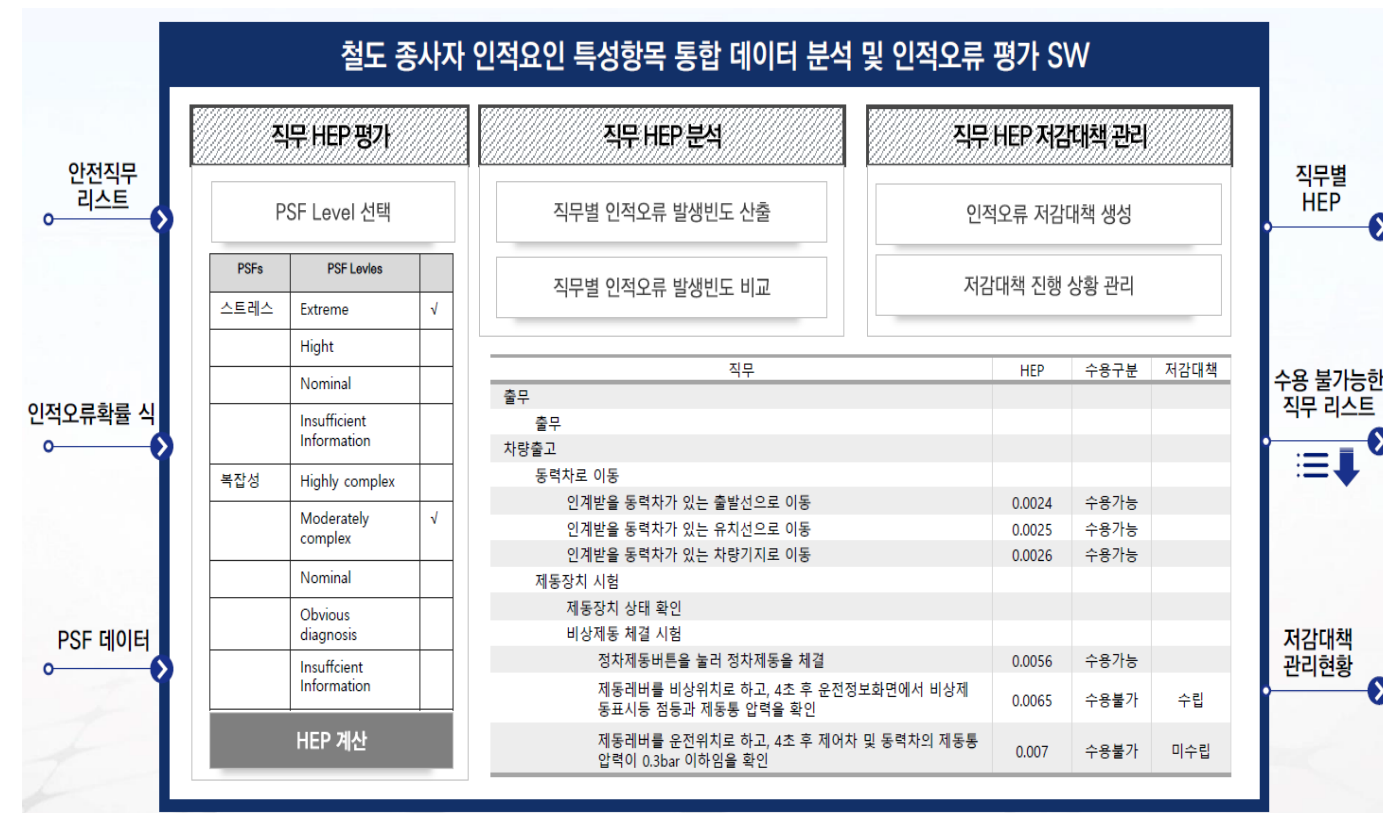
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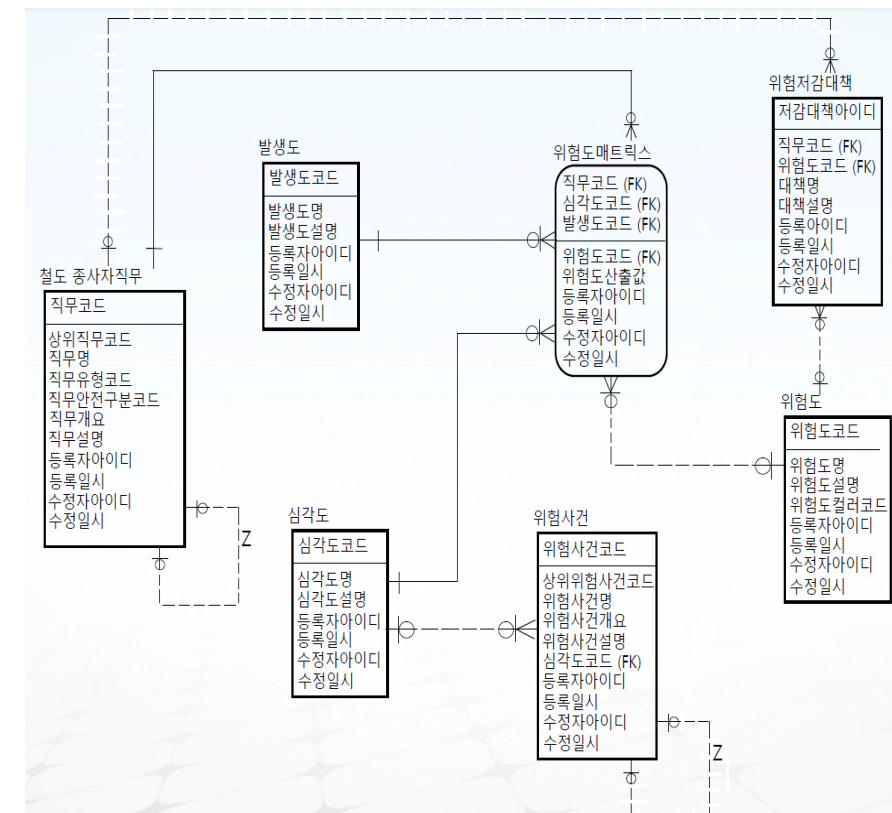
Railway Personnel Human Error Evaluation·Prediction Integrated Management System

Integrated data analysis of human factors characteristics and human error evaluation software for railway workers

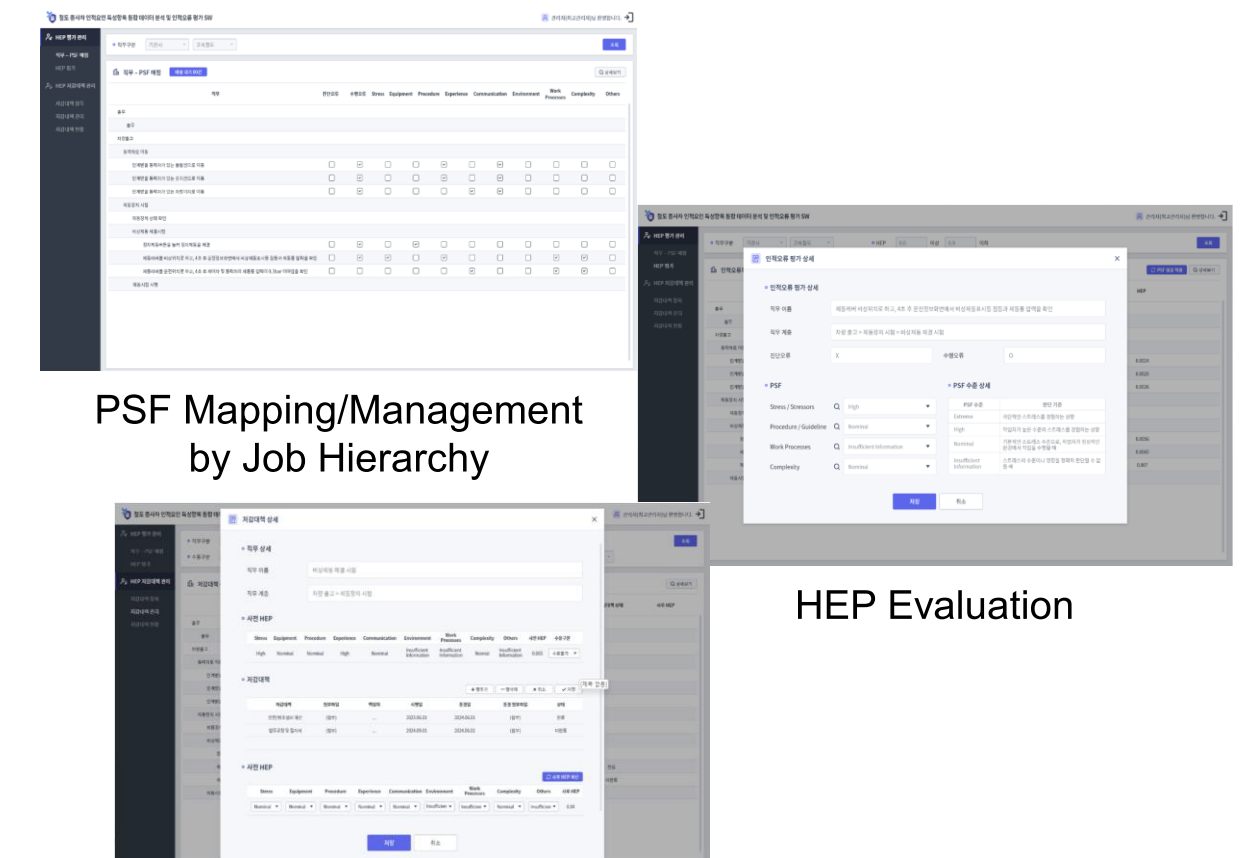
- Module architecture and detailed data design for integrated data analysis of human factor characteristic items for railway workers and human error evaluation
- UI and Function Configuration Based on Designed Architecture



Module architecture design



Database detailed design

Human error reduction measure
management

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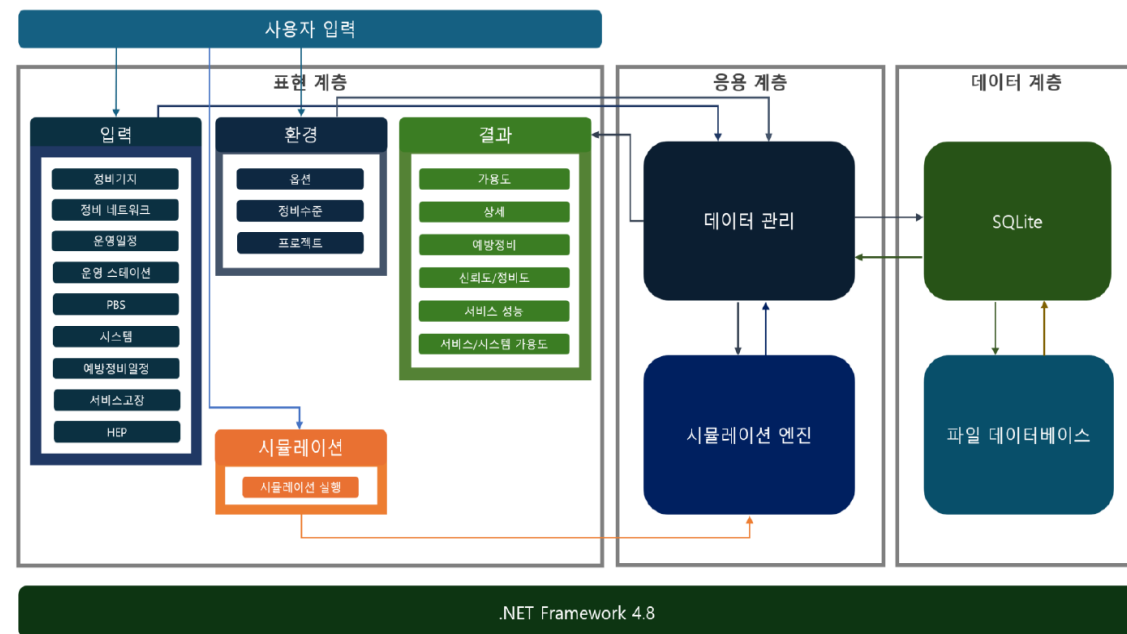
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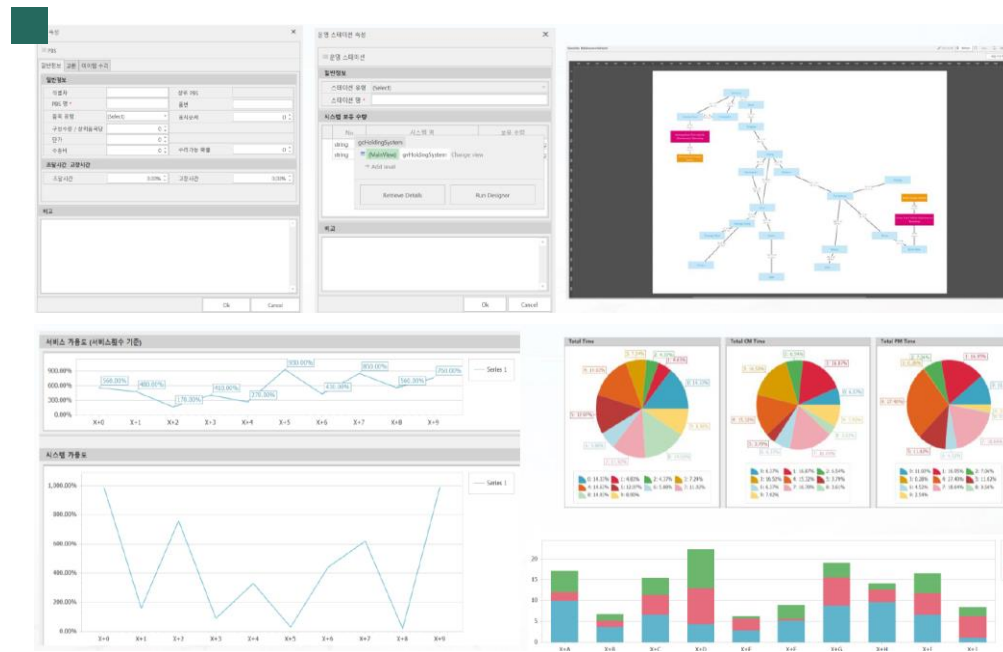
Railway Personnel Human Error Evaluation-Prediction Integrated Management System

Human Error Prediction SW based on Cyber-Physical System for Railway Workers

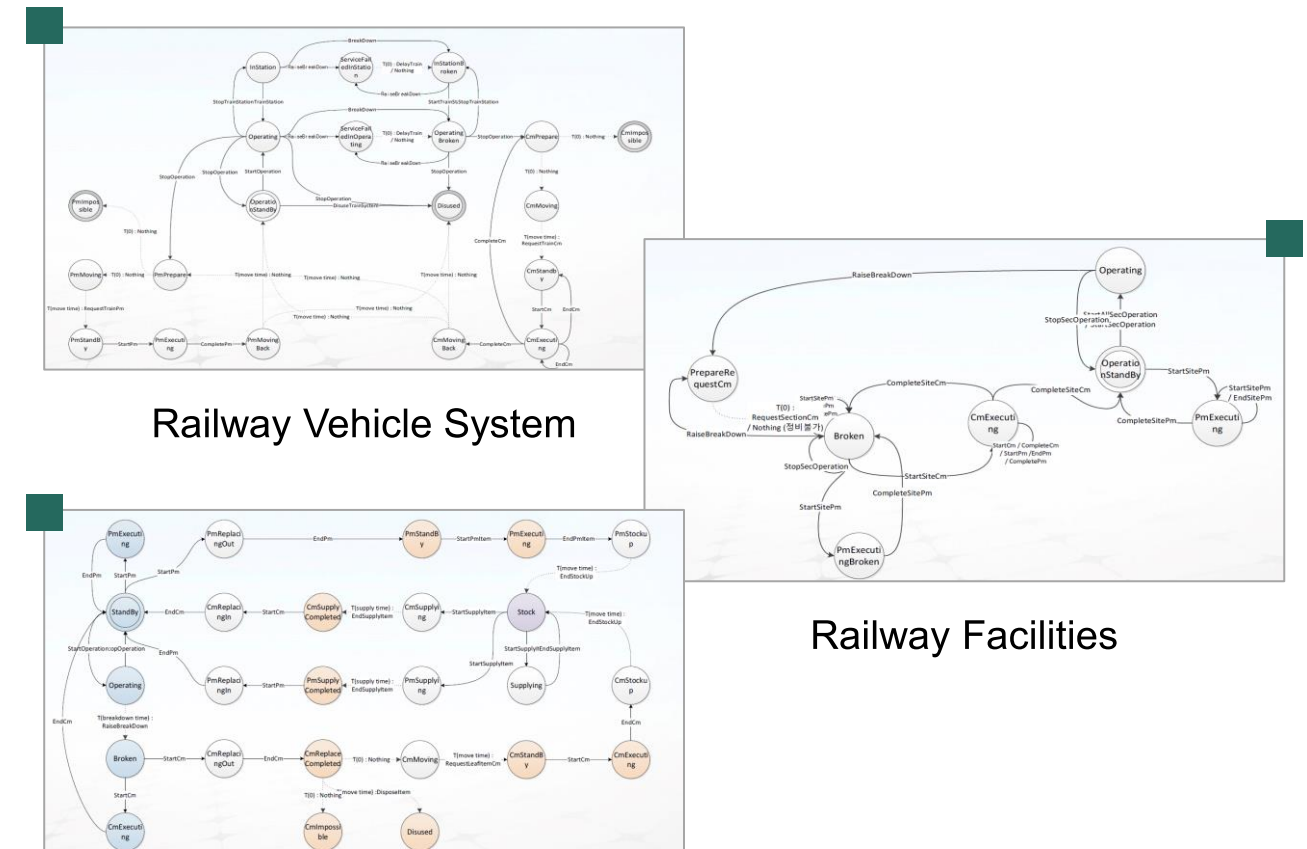
- Virtual physical system-based human error SW framework for predicting human error of railway workers creation and function, detailed design
- Simulate the overall situation, including the probability of human error items, and present RAM management indicators for it



Human Error Prediction SW Framework



SW Function Design and Screen Design



System Subcomponents



Sub-theme: Risk Control and Management

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Multi-railway worker joint virtual training system for responding to unusual situations

Multi-railway worker joint virtual training system for responding to unusual situations

Purpose

Securing a virtual reality-based railway worker education-training system and feedback technology for human factor characteristic data for the prevention and early response to accidents and disruptions caused by human factors

AS-IS

- Although safety education and emergency response training are conducted for workers, a joint training system for workers to prepare for emergency situations is insufficient

- There are limitations in systematic-scientific human factor prevention management due to insufficient linkage between worker safety education and safety management data.

Research Task

Unusual Situation Response
Joint Virtual Training System

Real-Time Diagnosis System for
Training Effect Based on Human
Factors Characteristics

- Development of VR content for each railway accident-failure scenario
- Development of a module linking human error characteristics DB and virtual training feedback data
- Development of a trainee biometric signal collection system
- Development of a virtual training system based on human error DB and virtual training feedback data

- Production and automatic generation SW of scenarios for railway accident-failure training
- Real-time comprehensive analysis SW of training effects based on biometric signals
- Development of virtual training system operation procedures-guidelines-manuals

TO-BE

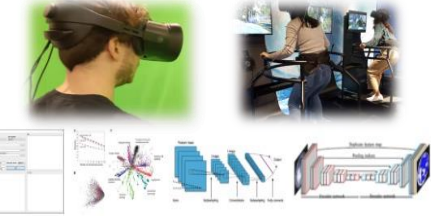
- Response to unusual situations by railway personnel and reduction of human error through field deployment and operation of joint virtual training for multiple users

- Operation of scientific evaluation-inspection for railway workers' job performance and safety management capabilities

- Linking-utilizing worker safety education and safety management data, improving weaknesses for each worker

Virtual
Training
SW

Training effect and real-time comprehensive analysis software based on biometric signals of fatigued trainees



Software for scenario creation and automation for railway accident/failure training



Virtual
Training
SW

Early response to abnormal situations
Integrated/individual virtual training full system



Early response to abnormal situations
Integrated/individual virtual training compact (Light) system



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Multi-railway worker joint virtual training system for responding to unusual situations

Full-scale system for joint/individual virtual training in early response to abnormal situations using technologies such as wearables and IoT

■ Completed ■ Partially Completed ■ Next Stage

① Development Specification Conformity

② System Function Definition Compliance

③ Detailed Design Document Compliance

④ Core Function Suitability

⑤ Prototype Suitability

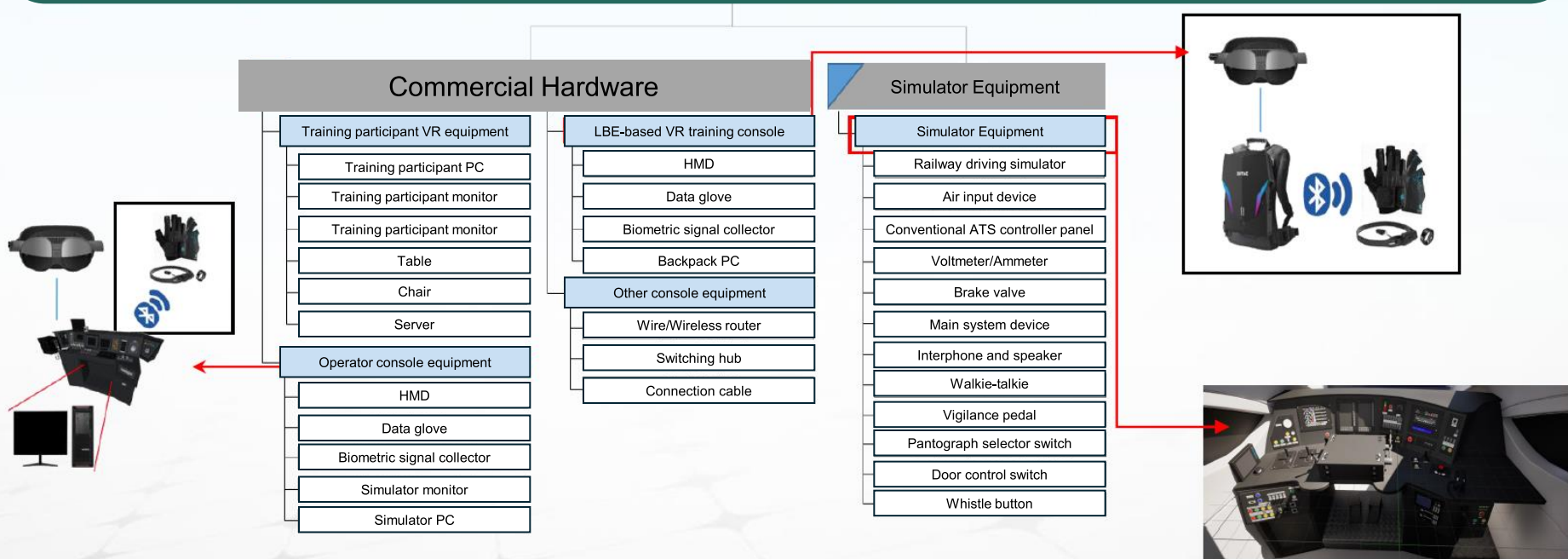
⑥ Prototype Official Quality Certification Test Report

⑦ Prototype Pilot Operation Result Report Suitability

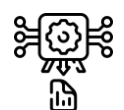
Stage Research Achievements

- Joint Virtual Training Full(Full) System HW Basic/Detailed Function Design
- Joint Virtual Training System Hardware Configuration Items and Components Design

Integrated Virtual Training System (Full System) Hardware Configuration (HWCI) for Multi-user Railway Worker Response to Abnormal Situations



Input Data



VR Data



Scenario



Storyboard



Personal Avatar



Scenario A



Scenario B



Scenario C



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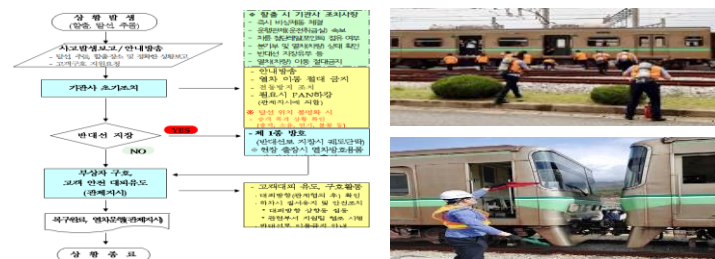
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Multi-railway worker joint virtual training system for responding to unusual situations

Real-Time Diagnosis System for Training Effect Based on Human Factors Characteristics (SW)

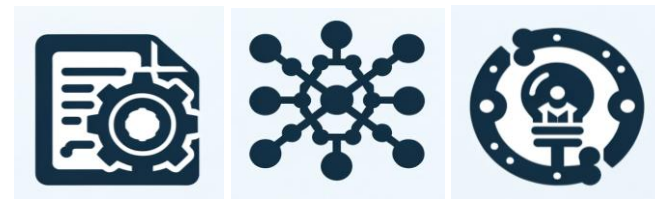
Requirement Derivation

Analysis of existing accident situation training



- ✓ Understanding the status of safety education
- ✓ Analysis of training action flowcharts
- ✓ Derivation of improvement needs

SW Requirement Derivation



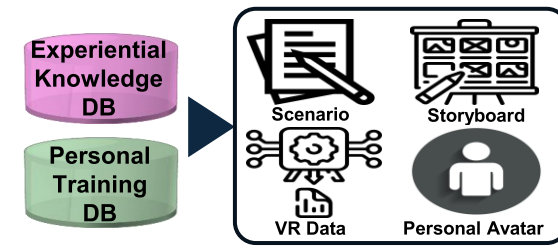
Auto-generation Mock Logic VR System

Training Requirements

- ✓ Define training requirements for each function such as simulation logic, content, avatar management, scenarios, and events

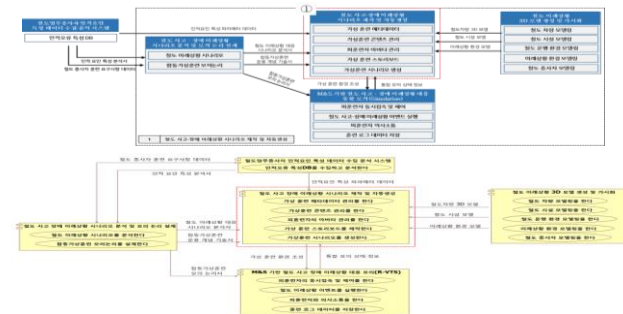
Scenario Generation

Scenario Generation SW Function Definition



- ✓ Detailed Function Requirements Definition

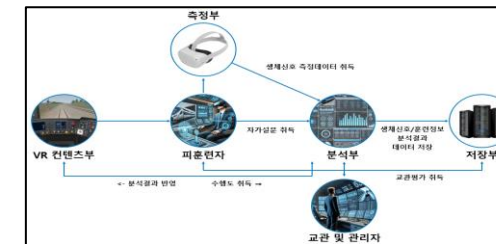
Architecture / Use-case Design



- ✓ Abnormal, Emergency Scenario Architecture
- ✓ System Function Use-case Diagram

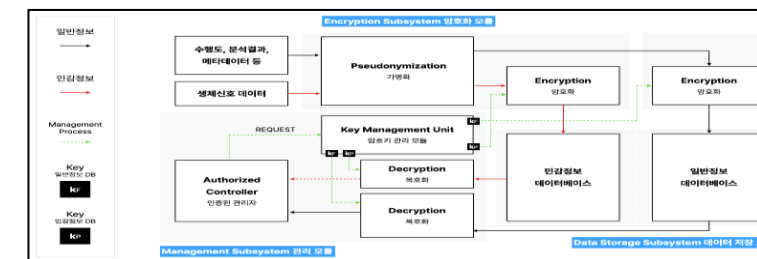
Real-Time Analysis

Biometric Signal-based Training Effect Analysis SW Detailed Function Design



- ✓ Overall System Configuration Design
- ✓ Signal/Performance Ratio Distribution Design (AI-based)

Detailed Design of Storage/Management Function



- ✓ Design of Encryption/Storage/Management Module for Biometric Signal Data

Systematic Operation

Operational Plan for Utilization



- ✓ Derivation of institutionalization measures for the operation of the virtual training system
- ✓ Development of evaluation criteria for institutionalization

Research on Legislation for Operation



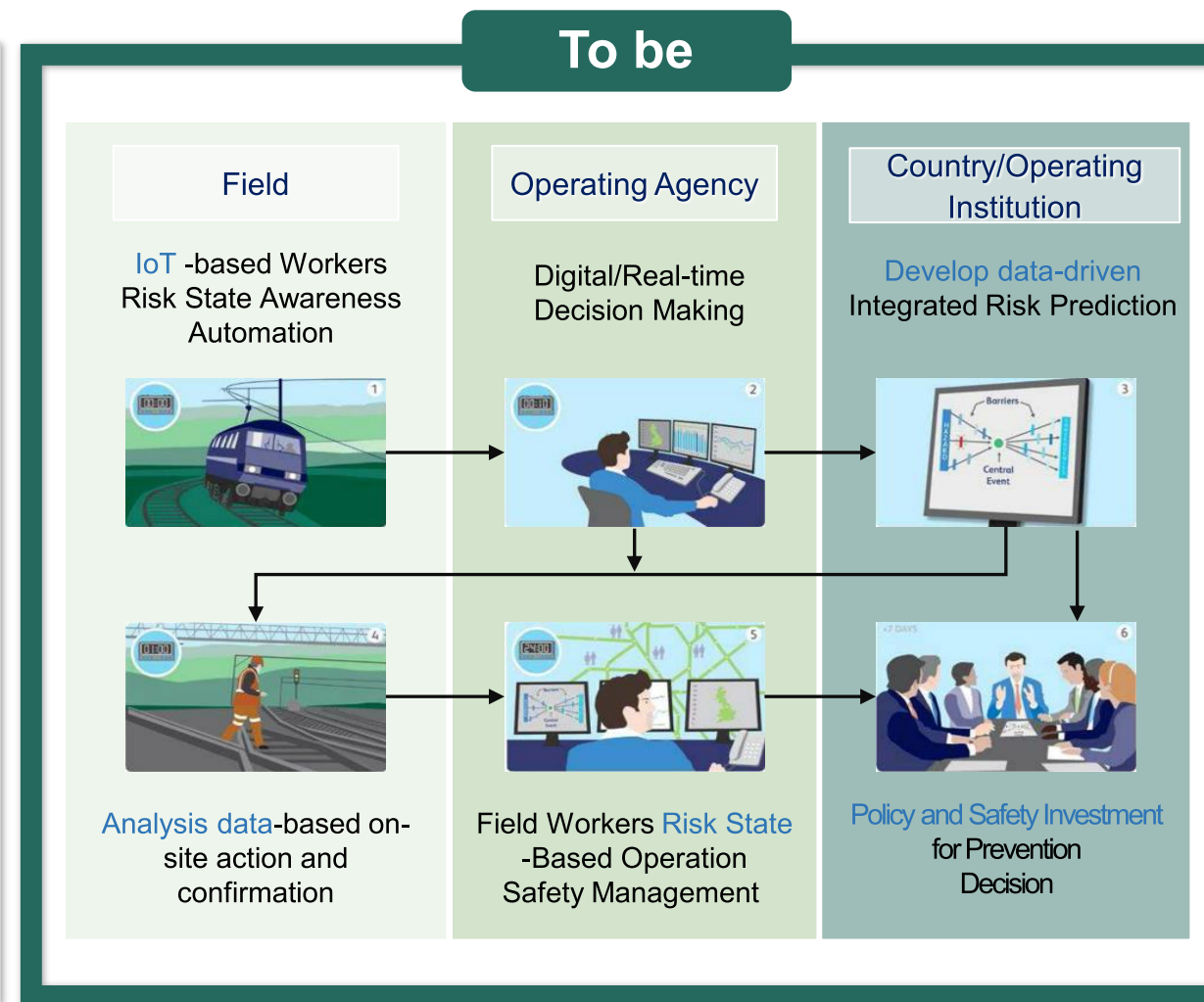
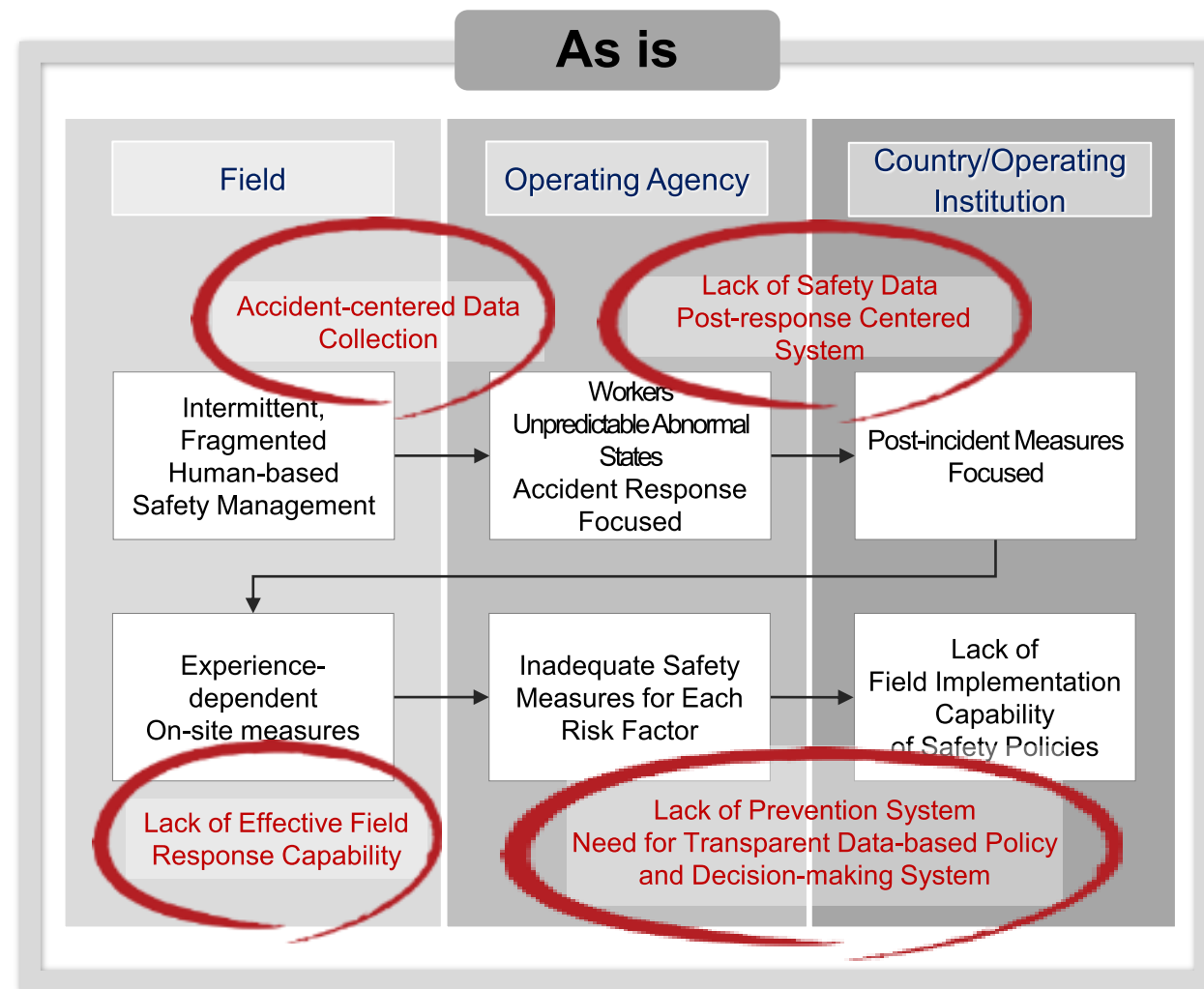
Manual Revision Impact Analysis Report Legislation/Revision

- ✓ Railway Safety Management System Manual Revision
- ✓ Preparation of Legal Regulation Impact Analysis Report
- ✓ Legislation and Technical Standards Revision

Multi-railway worker joint virtual training system for responding to unusual situations

Establishment of a data-based proactive human factors management system for railway workers

- Railway Worker Safety Data+ Human Error Diagnosis + Human Error Analysis/Evaluation/Prediction + Railway Safety Management System



**From Post-response
Approach
to Data-based Proactive
Response
System in Railway Safety...**



Sub-theme: Risk Control and Management

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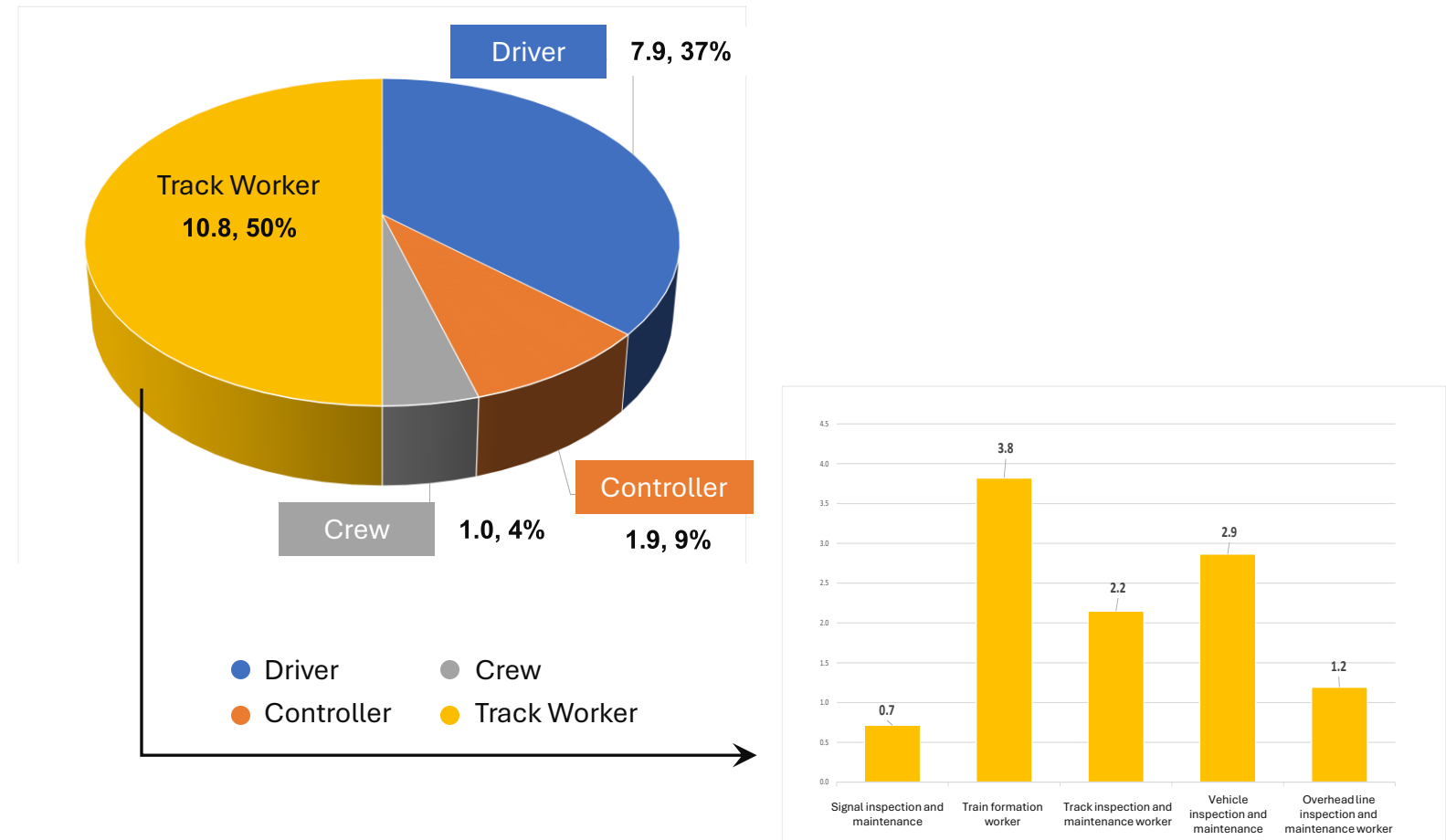
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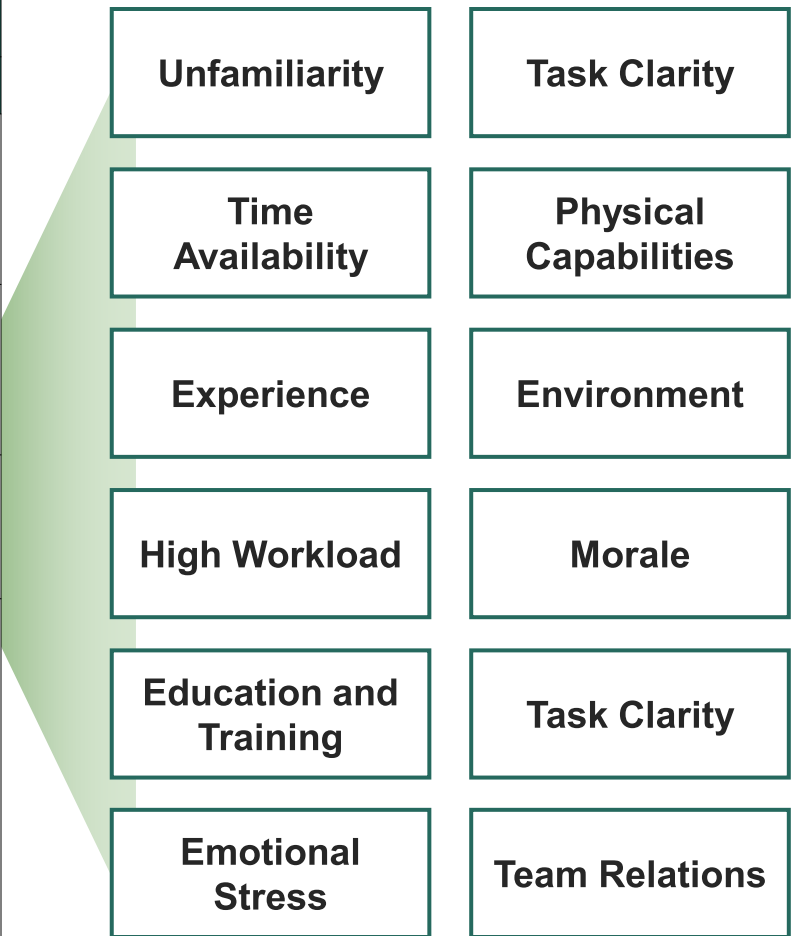
Multi-railway worker joint virtual training system for responding to unusual situations

50% reduction in accident frequency by improving human error influencing factors for railway accident workers(21.6/yr → 10.6/yr)

- Improvement of Human Error Influencing Factors(Analysis/Evaluation/Prediction/Management: 16.0%, Training: 17.1%, Operation Support: 16.0%)



Workers	Accident Type	Annual Occurrence Frequency	
		AS-IS	TO-BE
Driver	- Vehicle Collision/Derailment - Speeding - Signal/Instruction Handling Error - Train (Vehicle) Abnormal Stop/Retreat - Train Brake Connection Delay/Non-connection	7.9	3.9
Controller	- Vehicle Collision/Derailment - Signal Disruption - Incorrect Signal Handling - Track Switching Error - Train Operation in Work/Construction Area	1.9	0.9
Crew	- Train Door/Facility Entrapment - Employee Falling During Vehicle Boarding/Alighting - Train Collision/Derailment - Incorrect Signal Handling	1.0	0.5
Track Worker	- Unauthorized Work on Trackside - Workplace Fall/Trip - Electric Shock - Negligence in Vehicle Access Control - Negligent Train Protection - Vehicle Derailment - Caught in Work Equipment - Impact from Flying/Falling Objects - Vehicle Damage - Tripping on Platform (Station) - Insufficient Maintenance - Train Separation	10.8	5.3



Sub-theme: Risk Control and Management

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Multi-railway worker joint virtual training system for responding to unusual situations

Expected Effects

- Addressing societal demands for employee safety following the strengthening of worker safety under the Industrial Safety and Health Act and the introduction of the Serious Accidents Punishment Act
- Contributing to the government's railway safety policy by preventing train accidents and casualties caused by human error among railway workers
* '3rd Comprehensive Railway Safety Plan', '9th National Transportation Safety Master Plan', 'Smart Railway Safety Management System Establishment Master Plan', etc.
- Proactive prediction and management of human errors by railway workers to reduce social costs through the reduction of railway accidents·disruptions
- * Damage reduction costs are expected to be approximately 500 billion KRW for 8 years (from 2032 to 2039) (Business Planning Report , 2019)
- Promoting the export of developed technology and technology transfer to domestic and international railway operating agencies and manufacturers
- Significantly reducing the burden of training high-level technical personnel, contributing to the long-term job creation of such personnel



Yulchon Station derailment accident ('16.4), train driver ignored speed limit



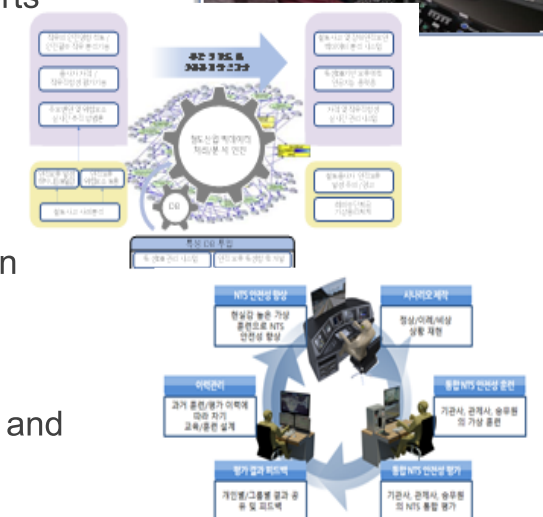
KTX derailment accident ('16.4), communication error between train driver and controller

AS-IS

- Lack of technical solutions to detect and prevent human errors in workers in advance by sensing abnormal states, incorrect habits, etc.
- Insufficient technological solutions to scientifically analyze and improve the root causes of human errors among railway workers
- Safety training and non-routine joint simulation exercises are conducted, but there are limitations in joint response capability for abnormal situations

TO-BE

- AI-based human factor characteristic data analysis supports safe operation of railway workers and operates the job suitability evaluation system's field reporting
- Analysis of human factor data, prediction, CPS-based simulation training system field reporting and operation
- AI - Big Data-based railway worker competency evaluation and verification system field reporting and operation
- Analysis of abnormal situation response and process improvement measures for each task/user, field reporting and operation of a cycle-oriented competency evaluation and inspection system for railway workers



Sub-theme: Risk Control and Management

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