DATA-BASED SMART RAILROAD TECHNOLOGIES FOR PREVENTIVE SAFETY MANAGEMENT

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Text Division.

There are limitations in preventing sporadic railway failures and accidents caused by various reasons with existing safety management technologies. Recently, Korea has planned to develop new technology using the rapidly developing fourth industrial technology such as ICT, IoT, Big Data, and AI. In this paper, we would like to introduce the following data-based smart railway safety technologies that have promoted in Korea; 1. IoT-based railway site safety big data construction and smart preemptive response technology, 2. AI-based railway operation safety analysis, prediction, and decision-making technology, 3. Big data-based integrated railway safety management system technology. We would like to introduce Korea's safety plan.

Keywords: Railroad Safety Mangement; Risk Mangement; IoT-based Safety Monitoring; AI-based operation safety analysis; Big data-based integrated safety management

1. Status of Railway Safety Management in Korea

The number of railway users in Korea is 5 billion per year, which means 50 million citizens of Korea use it over 100 times a year. The ratio of rail transportation is 35%, and passenger density and train operation density is one among the highest in the world. It operates a total of about 6,000 km length-wise, with 25,000 railway vehicles, 1,670 stations, and about 60,000 railway workers.

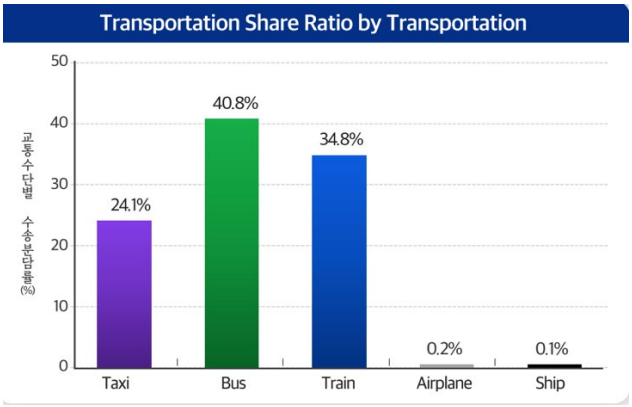

Fig.1. Transportation share ratio by transportation

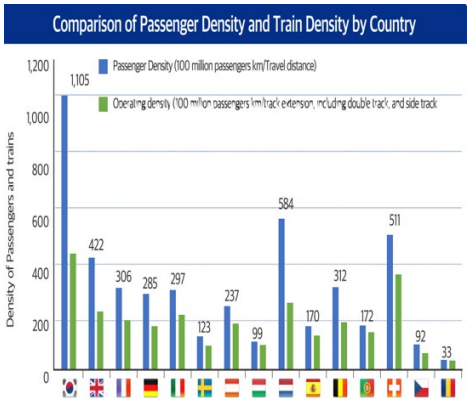

Fig.2. Comparison of Passenger Density and Train Density by Country

Daegu subway accident caused 192 casualties occurred in 2003. Accordingly, the Railway Safety Act, which consists of the Railway Safety Management System, the Train Operation System, and the Maintenance System were established in 2004 for railway safety management at a national level since the accident.

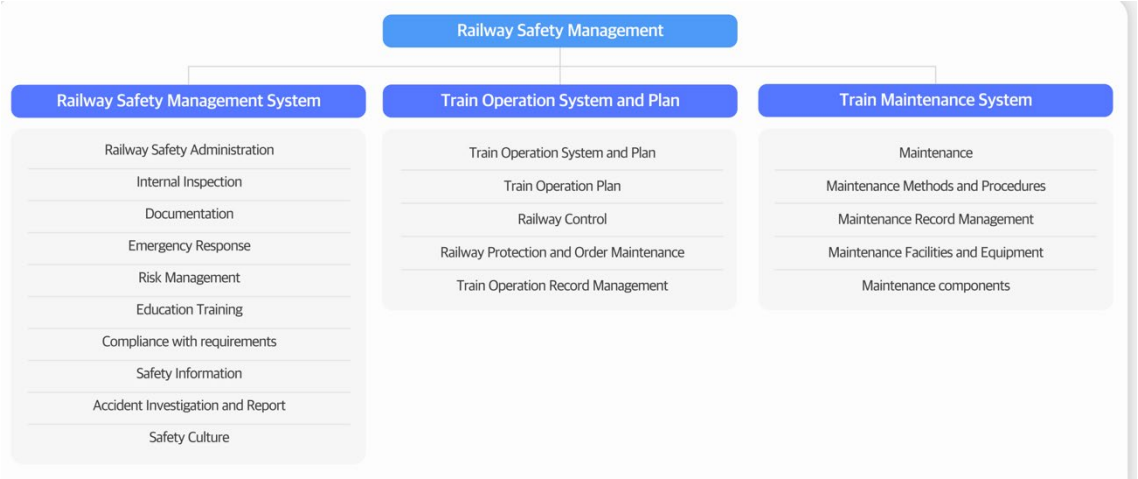

Fig.3. Configuration of the Railway Safety Act in Korea

Afterward, Korea has been making efforts continued to improve railway safety. Currently, the number of train accidents and deaths in Korea has dropped by more than 80%. The death toll is top 2 worldwide as of 2019, and the level of major accidents remains among the top in the world.

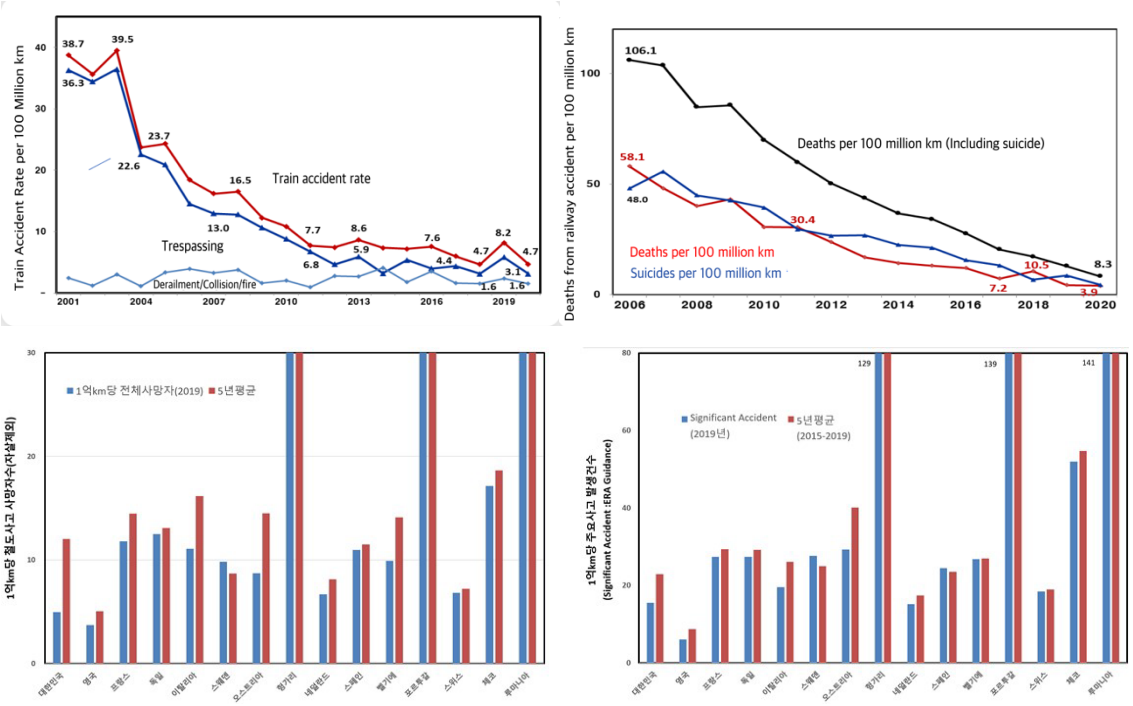

Fig.4. Railway Safety Levels of Korea

Nevertheless, large and small railway accidents are still occurring time and time again. Several years do not meet the goal safety level according to the current status of railway accidents since 2011. The safety indicators have been in gridlock since 2015 and accidents have been increasing again since 2018. Furthermore, time delay accidents which increase public transportation have been increasing since 2017.

More than 3 trillion won is being invested for railway safety by state coffers in 2021, which has increased in investment worth yearly since the 1 trillion won invested in 2015. Since railways are a mass transportation system, social losses, such as large-scale human and material damage and public inconvenience, are followed by the accident. The case of a derailment accident on the Gangneung Line in 2018 caused 15 people to be injured and 22 billion won in property damage, and it took two days of overnight restoration. In this way, such safety accidents have caused social and economic losses with human and material damage reaching 580 billion won and maintenance costs reaching 5.89 trillion won over the past 3 years.

2. Issues and Problems of Railway Safety Management in Korea

The state has put continuous effort to improve railway safety, but accidents and disorder continue to occur repeatedly, resulting in human, material, and social damage.

As the railway operating environment is affected by social and technological aspects and constantly changes, there is an uncharted territory of various potential risk factors for railway safety accidents that have never been experienced before. The main cause of these railway accidents is aging of vehicles and facilities, limited budget to address the

problems, the scale, and frequency of natural disasters, the reduction of maintenance personnel contradictory to the increase of railroad network, and new transportation such as unmanned driving, and increased crime and terrorist threats. These factors require preemptive action before it leads to massive accidents.

In Korea, a safety plan on a 5-year basis has been established, and recently a smart railway safety management system has been established to build a prevention system. To execute the plan, technology to perform risk diagnosis/analysis/prediction of various accident risk factor data and preemptive response to prediction is required. Also, technology development is required to achieve policy objectives to improve railway safety and to resolve or mitigate the potential of various unseen safety accident risk factors and the dramatic rise in railway safety management costs.

Fig.5. Current status of the policy change in Korea

3. The Concept of Data-Based Smart Railway Safety Management Technology and Prospect

Recently, the introduction and utilization of fourth industrial technologies such as ICT, IoT, Big Data, and AI are significantly active throughout the science and industry. The 'smartization' of railways is no exception, and an active response is necessary for railway safety. Hence, it is necessary to introduce smart technology to establish a preventive system for railway safety management.

Establishing a preventive system step by step to improve railway safety management is necessary for Korea. This study intends to develop real-time damage diagnosis technology using digitalization and by constructing a big data platform through monitoring safety risk factors at railway sites and standardizing risk factor data in the first and second stages. In the third stage, it is required to develop a technology able to analyze the systematic risks and conditions of railways, predictive technology using AI, and for the fourth stage, efficient decision-making technology based on predictive results would be required.

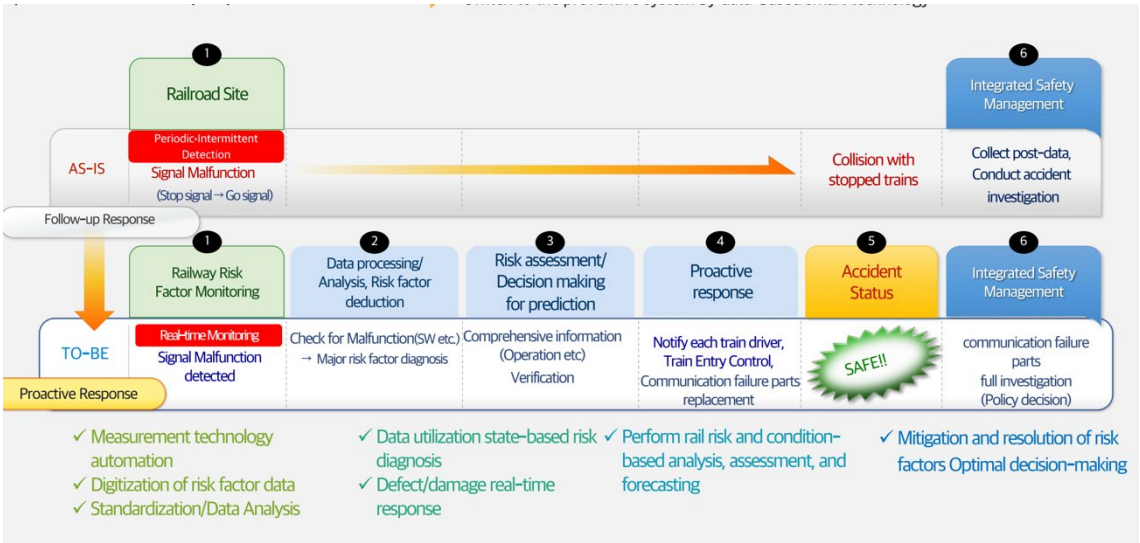

Fig.6. The Concept of Data-based Smart Railway Safety Management Technology

Activities that may lead to risk factor prediction diagnosis, risk factor analysis and prediction, prediction-based decision-making for precautionary purposes, and preemptive response are defined as 'safety chains', and 'digital safety chains' refers to when those digital chains are connected to digitized data. The implementation of digital safety chains is essential for proactive prevention and preemptive response.

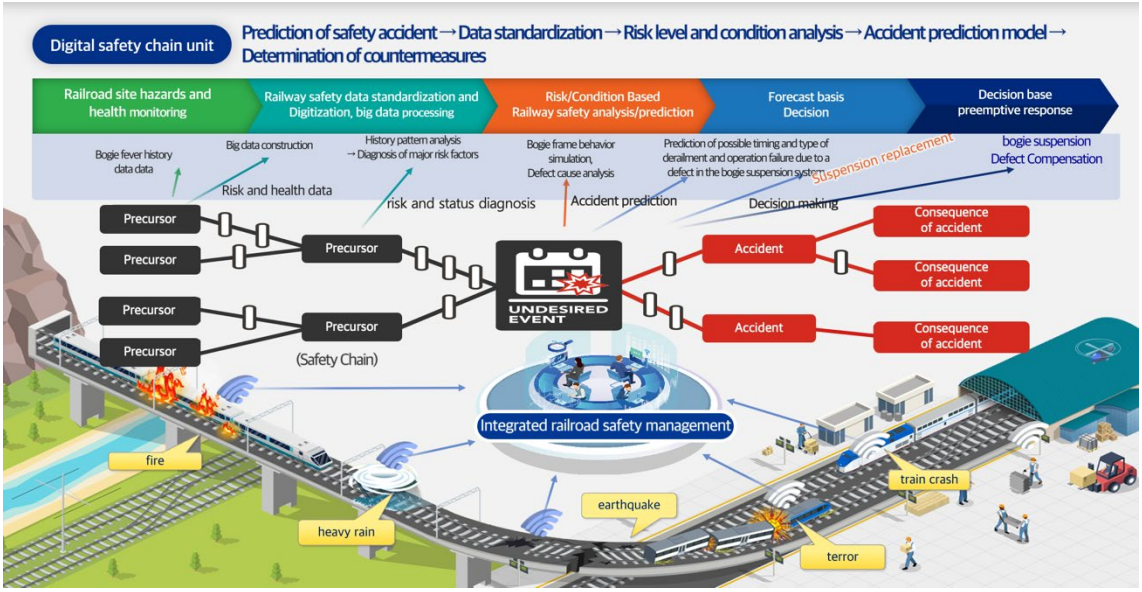

Fig.7. Advanced Prevention System Using Digital Safety Chain

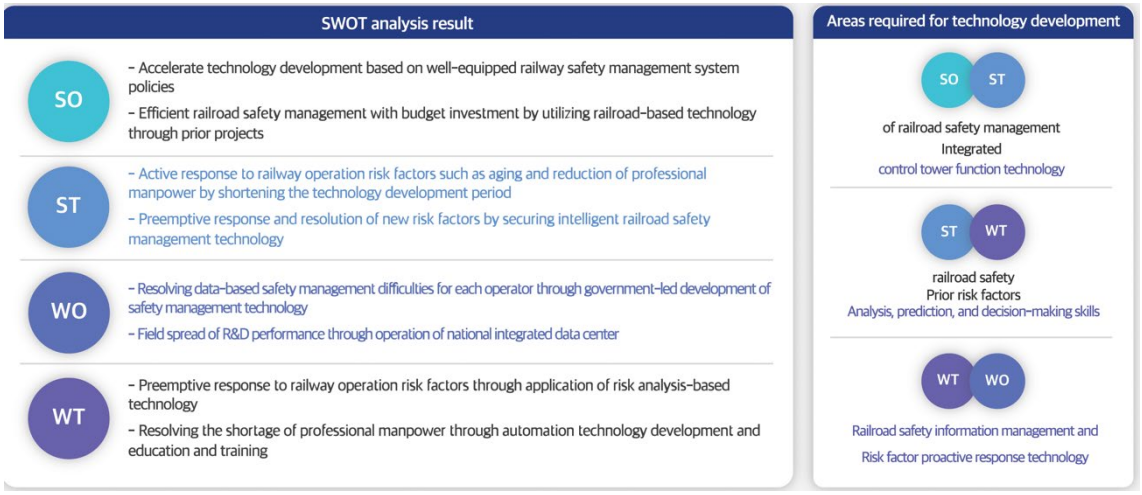

Fig.8. Development of Data Based Smart Railway Safety Management Technology

The following chart is the " Required Area for Technology Development" derived from the SWOT analysis results. The three areas are 1) Integrated functional control tower technology for railway safety management, 2) Precautionary analysis, prediction, and decision-making technology, and 3) Railway safety information management technology and risk response technology. This study will promote the railway safety management project that combines these three technical matters.

4. Goals of Developing Data-based Smart Railway Safety Management Technology

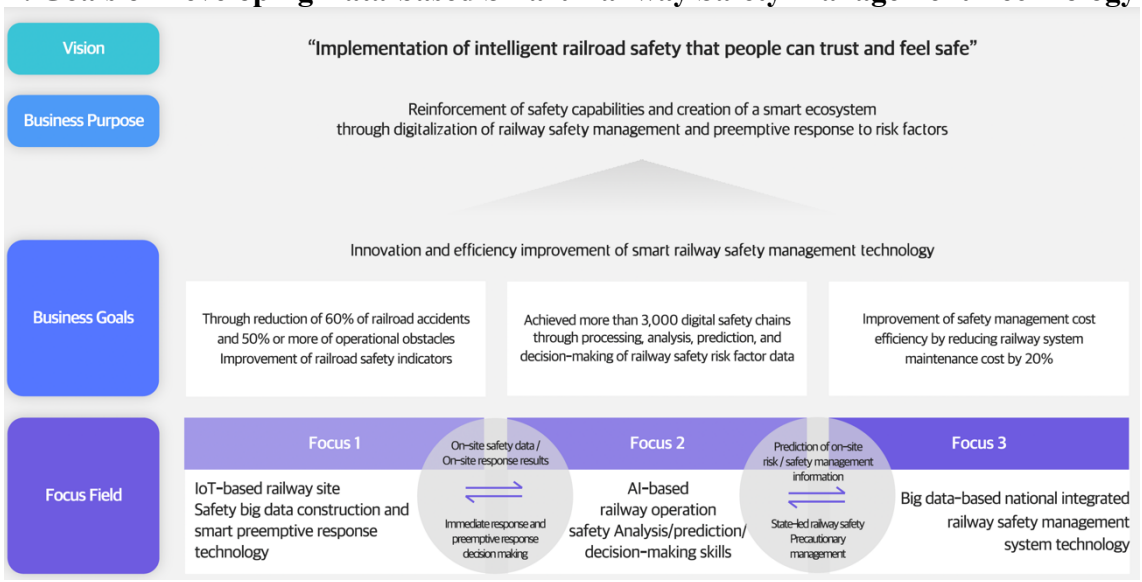

Fig.9. Goals of Developing Data-based Smart Railway Safety Management Technology

The purpose of this project is to strengthen the safety degree and safety capabilities by digitizing the current railway safety management and implementing preliminary prevention for risk factors.

The business objectives for this are as follows:

1) Improving railway safety indicators by reducing railway accidents by 60% and operating disturbances by 50% or more

2) Over 3,000 cases of digitizing safety systems for processing, analysis, prediction, and decision-making of railway safety risk factors data

3) Diversification of safety management investment items, i.e. cost efficiency, achieved by eliminating budget bias for safety management items by reducing maintenance costs of railway systems by 20%.

The three core developing areas for achieving the business objectives above are as follows.

preemptive/response technology for accidents and difficulties, and early response technology for railway vehicle and facility maintenance, and demonstration of integrated big data system for railway workers.

The second minor task of Core-1(Task 1-2) is "Developing Big Data and Smart Preemptive Response Technology for risk factors in Railway Facilities", which consists of developing risk and condition-based scenarios, data standardization, monitoring system, and real-time diagnostic technology system for any abnormalities.

The third minor task of Core-1(Task 1-3) is " Developing Big Data and Smart Preemptive Response Technology for risk factors in Railway Vehicles" and developing sensor technology for measuring a physical quantity on the vehicle and the ground to expand safety management items for railway vehicle core devices as well as the development of integrated information analysis technology for real-time data communication and analysis.

The second core area (Core-2) is "AI-based railway safety analysis/prediction/decision-making technology" and consists of four minor technologies. It is possible to realize a prevention system that makes an optimal countermeasure by analyzing, evaluating, and predicting using big data on risk factors such as vehicles, facilities, workers, and passengers of the railway.

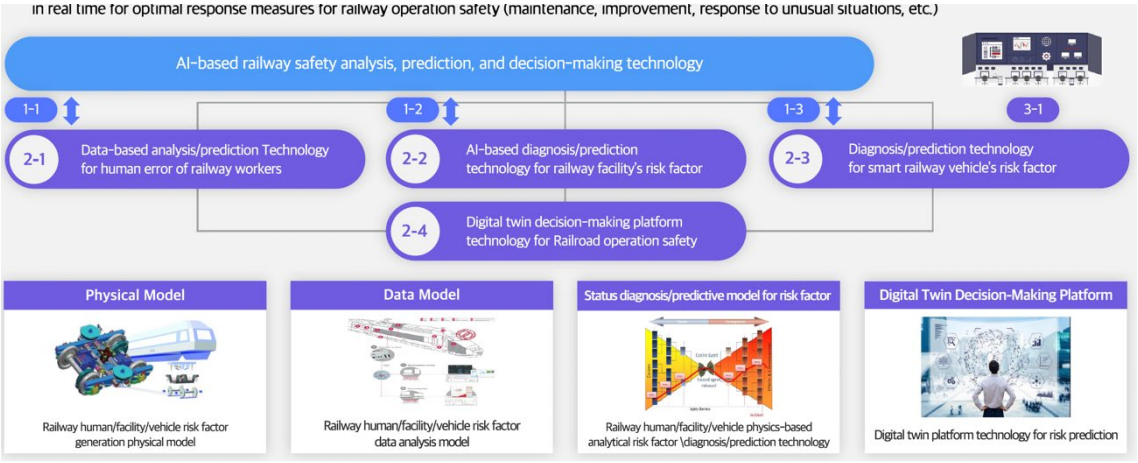

Fig.11. AI-based railway safety analysis, prediction, and decision-making technology

The first minor task of Core-2(Task 2-1) is "data-based human error analysis, prediction, and decision-making technology," which includes modeling human error mechanisms of railway workers and developing error analysis, prediction, decision-making artificial intelligence platform, and decision-making Cyber Physical System (CPS) technology for avoiding human error.

The second minor task of Core-2(Task 2-2) is "AI-based risk factor analysis, prediction, and decision-making technology for railway facility" in which decision-making technology makes economic and efficient decisions based on a risk factor analysis calculates various railway facility traits and behaviors.

The third minor task of Core-2(Task 2-3) is "Smart Rail Risk Factor Diagnosis/Prediction Technology". It involves condition diagnosis technology based on dynamic behavior traits of the railway vehicle's core device, risk precursor evaluation using the Bowtie model, and developing a tool for decision-making

The fourth minor task of Core-2(Task 2-4) is "Safe Operation Digital-Twin Decision-Making Platform Technology for Railway". It involves Bow-Tie modeling technology for the potential risk factors of the integrated railway system interface and developing an automated optimal decision support platform-based crisis management system.

The third core area (Core-3) is the "Big Data-based National Integrated Railway Safety Management System." It involves developing the smart railway integrated safety management system technology for the diagnosis, prediction, and decision-making of railway integrated safety risk factors for all operating institutions at the national level.

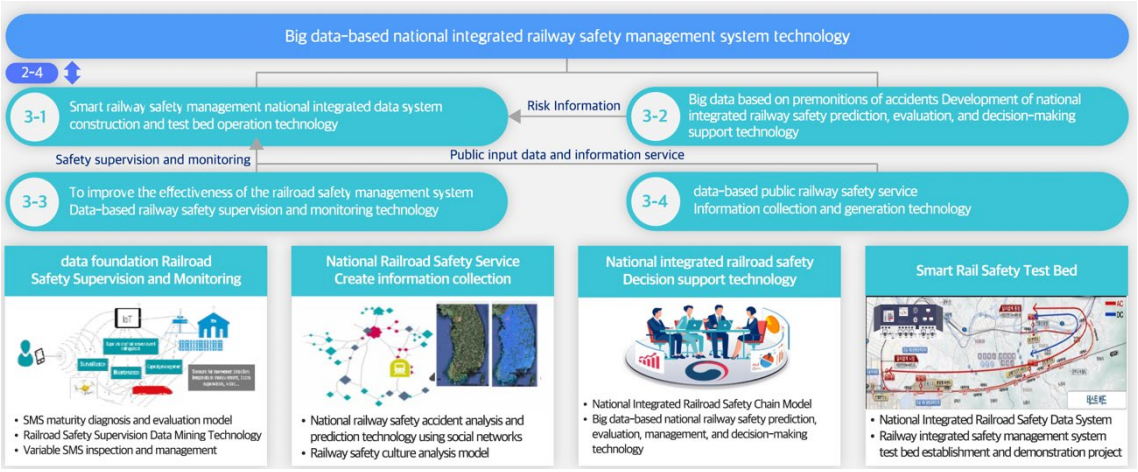

Fig.12. Big Data-based National Integrated Railway Safety Management System Technology

The first minor task of Core-3(Task 3-1) is ″developing a Smart national integrated data system for railway safety management and test bed management technology” and the second minor task of Core-3(Task 3-2) is “big data based national integrated railway safety analysis and prediction and decision support technology”. The key point of these tasks is railway safety decision-making for stakeholders based on safety information of all railways and the development of national integrated railway safety predicting, evaluation, and decision support technology to support PDCA.

The third minor task (Task 3-3) is "Data-based railway safety supervising/monitoring technology", and it involves developing a national safety management system for information evaluating/supervising/managing technology that enables self-inspection by operators and facility managers to improve the effectiveness of the railway safety management system and support autonomous safety improvement.

6. Technology development promotion strategy and plans for spreading

This project is a large-scale project involving around 1,500 researchers and a budget of 300 billion won. The railway safety information big data platform -the first stage of the project- will be developed and demonstrated in the third year as a major strategy and spread plan, and the second stage digital twin platform will be developed and demonstrated in the sixth year, and the final result, the National Integrated Safety Management System, will be developed and operated in the seventh year.

This study intends to verify the development technology for each stage through comprehensive testing of railway vehicles, power, and facility infrastructure using Korea's railway comprehensive test track. After the project is over, we would like to promote a plan to spread it to actual operating institutions nationwide after applying it to domestic business lines through a separate pilot project in the three-year gestation period.

7. Expected Results

The policy-wise expected results of this project are the early realization of the preemptive railway safety management system, the implementation of the core tasks of the Korean New Deal, the realization of smart railway safety R&D policies, and the achievement of world-class railway safety technology. For scientifical results, the safety level and indicators will be drastically improved by preventing accidents and difficulties through performance-based analysis of the domestic railway system, securing technologies that can preemptively respond to risks, and data-based railway safety management.

Conclusively, this study hopes to create high value-added jobs socially and economically, train manpower, reduce social and material damage caused by accident disorders, reduce direct damage costs, and reduce astronomical railway safety management costs.

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