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AI-Assisted Recovery System for Railway Signal Failures: Development and Deployment.

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Abstract

This paper reports on the development and deployment of an AI-based Failure Recovery Support System ("AI-Assisted Recovery System") designed to facilitate rapid restoration in the event of failures in railway signalling systems by leveraging knowledge from past failure cases. The system extracts similar historical cases, estimates potential causes, and proposes recovery strategies when a failure occurs, while also automatically generating the incident report that dispatchers traditionally prepare.

The AI model was trained on failure data accumulated since 2005, equipment manuals, and recovery procedure documents, enabling it to provide suggestions comparable to those of experienced personnel. The system has been in operation within the Tokyo Operation Control Center (OCC) since 2023, and demonstration tests confirmed that it can reduce recovery time by approximately 50%.

Furthermore, in 2025, generative AI technology was introduced to enhance the system, enabling automatic recognition and recording of operational conditions based on radio communications, as well as providing estimated recovery times and other advanced support functions.

Keywords: generative ai, occ, time-series sequence, ai-assisted recovery system, signal and communication control failure information database system, 1st gen., 2nd gen.

1 Introduction

Signal and telecommunication staff in the OCC are responsible for tasks such as coordinating maintenance activities, monitoring failures in signalling and telecommunication equipment, and responding to abnormal situations including equipment malfunctions. In particular, a high level of service reliability is required during commuter peak hours in the Shinkansen and the metropolitan area, and efforts are continuously made to minimize service disruptions caused by equipment failures. When disruptions do occur, rapid restoration (resumption of train operations) is essential, and early recovery is pursued through the use of various systems, including normal-state monitoring systems, equipment management systems, and the failure information database system managed by the signal and telecommunication dispatch center.

To address following challenges, we developed a railway signalling failure recovery support system that utilizes AI to assist recovery operations with the following objectives.

- -Accelerating initial response at the onset of failures
- -Reducing variability in recovery time caused by differences in OCC staff’s experience
- -Alleviating dispatcher workload during failure events.

The initial version of the system, referred to as the 1st Generation (1st Gen.), has been in practical use since March 2023.

2 Issues in searching for similar cases at OCC

At JR East, when equipment failures occurred, OCC staff frequently referred to past similar cases to help determine appropriate recovery methods. To support faster restoration, they used the Signal and Communication Failure Information Database System.

This system, introduced in 2005, centrally manages failure data related to signal and communication equipment within the JR East service area. It is also used for preventive maintenance by analyzing the number of failures and their trends [1].
Figure 1 shows the configuration of the Signal and Communication Control Failure Information Database System.

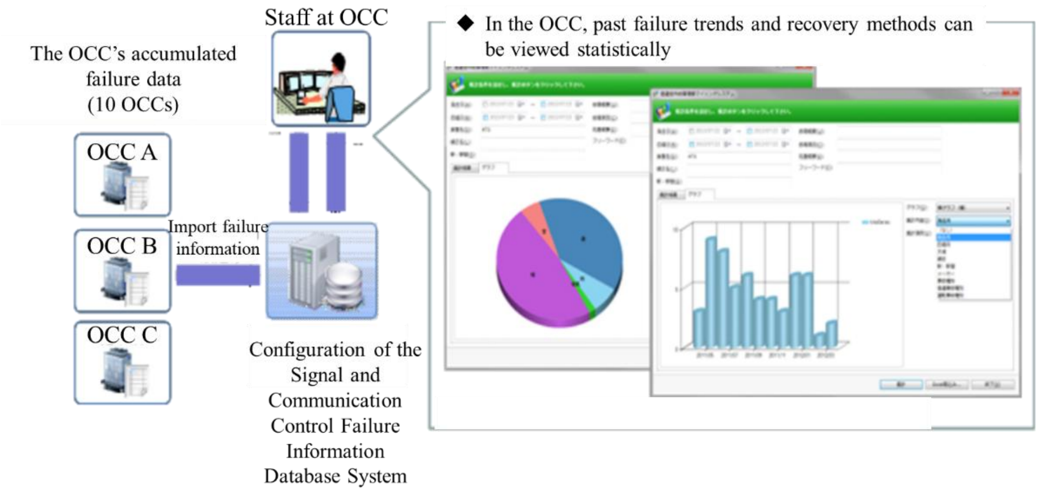

Figure1: Configuration of the Signal and Communication Control Failure Information Database System

The failure information data includes items such as an overview of the incident, location, equipment information, personnel involved, time-series sequence, details of the corrective actions, and the impact on train operations, such as total delay minutes and the number of affected trains.
In particular, the corrective action details contain not only the measures taken by staff at OCC during the equipment failure response, but also information about failures that were placed under observation, causes that were later identified, and any additional investigations conducted.
However, differences in staff at OCC experience created challenges, such as cases where "they were unaware that a similar incident had occurred in the past" or "they knew of a similar case but did not recognize its relevance."
As a result, the degree to which failure information retrieved from the Signal and Communication Control Failure Information Database could be effectively utilized varied among staff at OCC.
To address this variability—identified as one of the issues to be resolved for faster restoration—we aimed to develop an AI-Assisted Recovery System.
The goal was to enable accurate suggestions of past similar cases, equipment failure causes, and corrective actions from the Signal and Communication Control Failure Information Database System, regardless of the OCC staff's individual experience or expertise.

3 AI-Assisted Recovery System (1st Gen.)

3.1 Design Concept

The design concept of the system was to enable the "AI-Assisted Recovery System"—functioning as the equivalent of a highly experienced OCC staff who is knowledgeable about a wide range of past cases—to take over a portion of the OCC staff's tasks and provide the necessary technical information. This allows OCC staff to concentrate on the decisions and on-site instructions required for restoration.

Point (1): Mitigating OCC staff's workload during failure incidents
When a failure occurs, OCC staff face a heavy workload, including contacting related parties and understanding the evolving situation. Therefore, a key design requirement was that the introduction of the AI-Assisted Recovery System should not increase the workload of OCC staff.
To achieve this, the system was designed so that the AI-Assisted Recovery System automatically reads the time-series log file—a real-time, cloud-based textual record of conversations and updates exchanged between OCC staff and on-site staff, which OCC staff already create as part of their regular operations.
By automatically ingesting this file, the AI-Assisted Recovery System can grasp the situation and propose past similar cases, possible causes, and recommended corrective actions.

Point (2): Handling Rare Cases
Failures that many OCC staff have limited opportunity to experience are difficult to locate in the Signal and Communication Failure Information Database.
Therefore, the AI-Assisted Recovery System was designed to accurately propose low-frequency cases (hereafter referred to as rare cases) as well.

Point (3): Enabling Secure Use Across All OCCs
Since JR East has ten signal-related OCCs, the system needed to be usable at all locations. Therefore, the design aimed to ensure that the system could be handled securely on the business terminals already deployed at each OCC.
Specifically, although the system utilizes cloud-based services, technologies that isolate the environment from the public Internet were incorporated to ensure high security at low cost.
Furthermore, by adopting a web-based user interface, the system requires no application installation on the business terminals—which was a significant advantage at the time, when such terminals typically did not allow installing additional applications. This approach made it easy to deploy the system horizontally across multiple OCCs.

3.2 System Overview

Figure 2 shows a process flow of the AI-Assisted Recovery System (1st Gen.).
The development was conducted at the OCC in the Tokyo metropolitan area.
When an equipment failure occurs, a "time-series data log" is created and shared to support information sharing among OCC staff, on-site staff, and other related personnel from the moment of failure detection until restoration is completed.
This time-series data is text-based, and dispatchers record the time and details of events or actions in real time, such as:
"10:50 — Abnormal de-energized of relay indicated by system monitoring."

The AI-Assisted Recovery System uses this time-series data as input to the AI. Once the dispatcher begins creating the time-series data log, the AI automatically reads the log and proposes past similar cases and possible causes [Point (1)].
Figure 3 shows an example of the AI's actual suggestions.
The AI is trained using the data stored in the Signal and Communication Failure Information Database System, and it extracts and proposes similar past cases. In fact, even at the conventional line OCC, training the AI on all 210,000 failure records accumulated over the past 20 years was impractical due to workload and cost constraints. Thus, the system was made practical by limiting the target to approximately 3,000 failure records related to track circuits, which have a significant impact on train operations when a failure occurs.
To ensure that rare cases—those with very few occurrences—can also be extracted, tuning of the AI model was performed [Point (2)].
Furthermore, the system utilizes the e-smile Network, which was put into practical operation in 2019.
The e-smile Network is a communication infrastructure that links:

- ✓ a closed, JR-dedicated network jointly developed with telecommunications carriers,
- ✓ general cloud services, and
- ✓ internal corporate IT infrastructure,

all without relying on the public Internet.
For last-mile communications, the network integrates:

- ✓ regional IP networks that use optical communication,
- ✓ LTE-based wireless data networks, and
- ✓ the company's internal network infrastructure.

This configuration made it possible for all OCCs to achieve a secure and low-cost system architecture [Point (3)].

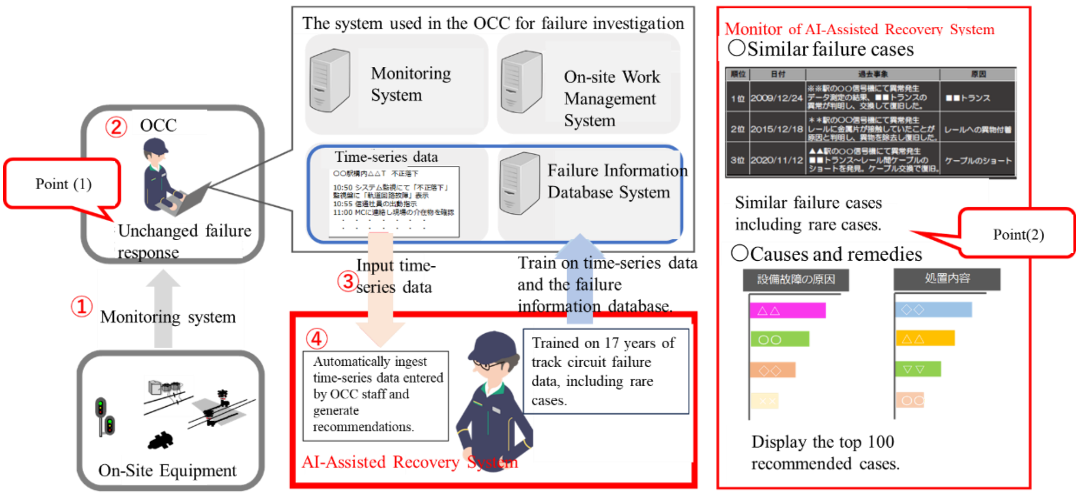

Figure 2: Process flow of the AI-Assisted Recovery System (1st Gen.)

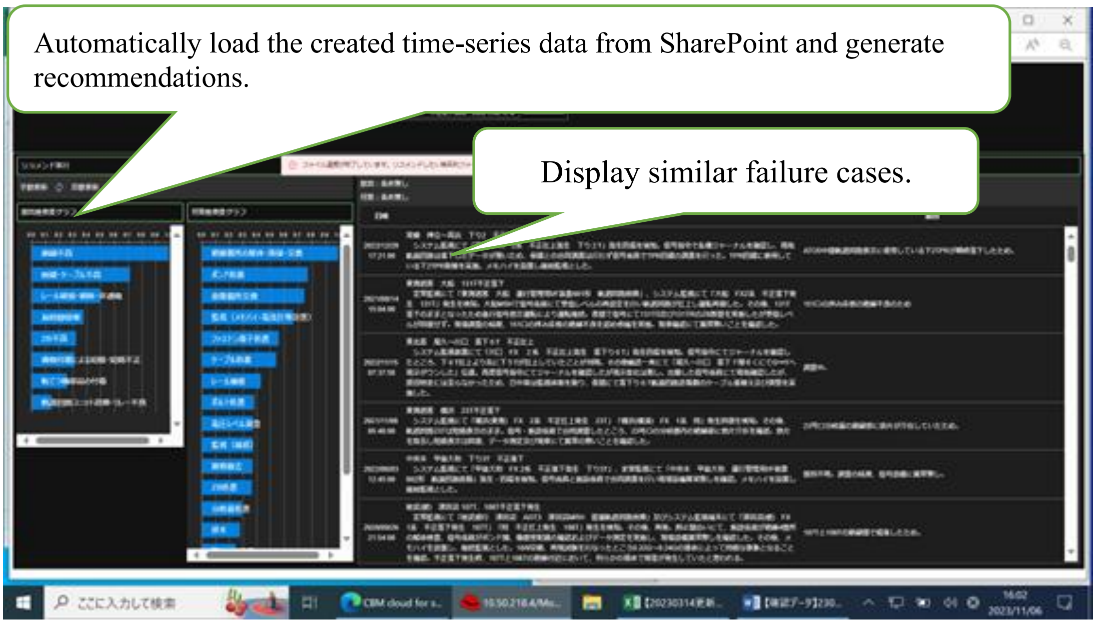

Figure 3: Example of the actual display screen

3.3 Pilot Test (from March 2020)

Starting in March 2020, we conducted a pilot test at the OCC in the Tokyo metropolitan area.

In this test, multiple staff evaluated the AI-Assisted Recovery System (1st Gen.) using a five-level scale, assessing aspects such as the validity of the AI's suggestions and the display of similar cases, equipment failure causes, and recommended corrective actions.

During the pilot test, there were several instances in which the AI proposed potential failure causes at an early stage—even for failures that had historically required significant time for restoration. Notably, in rare cases, the AI was confirmed to provide suggestions earlier than OCC staff.

Based on the results of the pilot test, further improvements were implemented in the practical development phase. These included parameters tuning to enable the AI to propose rare cases more accurately, as well as enhancements to the user interface—such as visualizing AI suggestions in graph format—to make the system easier for dispatchers to understand and better suited to actual operations.

3.4 Trial Deployment (2022–2023)

In 2022, after incorporating feedback from the pilot test, the system was trial-deployed as the AI-Assisted Recovery System to the OCC for conventional lines in the Tokyo metropolitan area.

Through interactions between OCC staff and the AI-Assisted Recovery System, the system was expected to contribute to faster restoration.

Figure 4 shows the scene of the trial deployment.

In this trial deployment, a case that previously required approximately two hours was shortened to about one hour, confirming a 50% reduction in restoration time.

Fig 4: Scene of the trial deployment

4 AI-Assisted Recovery System (2nd Gen.)

In March 2023, the system was put into operation at the OCC for conventional lines in the Tokyo metropolitan area.
In parallel, discussions about introducing the system to the Shinkansen OCC had begun in 2022. However, several issues arose regarding horizontal deployment: the large amount of work required of Shinkansen OCC staff during the rollout, the need to train the AI using Shinkansen-specific failure information, and the fact that Shinkansen OCC staff were unfamiliar with the system.
To address these challenges, we began exploring the use of generative AI from 2022.

4.1 Issues for Full-Scale Deployment

In considering the deployment of the AI-Assisted Recovery System to the Shinkansen OCC, we examined which aspects of the existing system would require modification. As a result, we found that the equipment configuration, the volume of data handled, and the characteristics of OCC operations differ significantly from those of the conventional lines in the Tokyo metropolitan area. This raised concerns that the conventional AI training approach might not provide sufficient support for failure restoration.
The main issues of the AI-Assisted Recovery System (1st Gen.) identified for horizontal deployment are summarized below.

Issue (1): Volume of AI Training Data
When the AI—trained based on the equipment used at the conventional line OCC in the Tokyo metropolitan area—was applied directly to the Shinkansen OCC, it was found that the system could not provide adequate support.

To retrain and retune the AI for the Shinkansen environment, the same extensive work that OCC staff at the conventional line had conducted over approximately three years would need to be repeated for the Shinkansen OCC.
Furthermore, the Shinkansen OCC manages not only signal equipment but also communication equipment, significantly increasing the number of equipment types. As a result, it was concluded that retraining the AI using the conventional approach was not realistic.
In fact, even at the conventional line OCC, training the AI on all 210,000 failure records was impractical due to workload and cost constraints.
Because the scale of Shinkansen operations is expected to be roughly 20 times larger, a fundamental revision of the existing approach was necessary. The required work included:
-Selecting cases for AI training where similar recovery actions would be expected in subsequent incidents
-Defining key terminology and applying consistent labels to all past cases
-Standardizing synonymous expressions to eliminate inconsistencies caused by variations in wording, and training the AI using the unified terminology

Issue (2): Frequency of Use in Daily Operations
After the system was put into actual operation, an evaluation of AI-Assisted Recovery System usage revealed additional issues.
With advancements such as enhanced self-diagnostic functions enabled by the digitalization of field equipment and the introduction of remote monitoring technologies, many failures could be diagnosed and resolved immediately without referring to the AI-Assisted Recovery System (1st Gen.) (Figure 5).
Specifically, for approximately 80% of all failures, the cause and corrective action were immediately clear at the moment of occurrence. As a result, the AI-Assisted Recovery System (1st Gen.) was used in only about 20% of cases.
Furthermore, even within this 20%, many OCC staff resolved issues instantly based on their own experience rather than relying on AI support. Consequently, the number of OCC staff using the AI-Assisted Recovery System began to gradually decline.

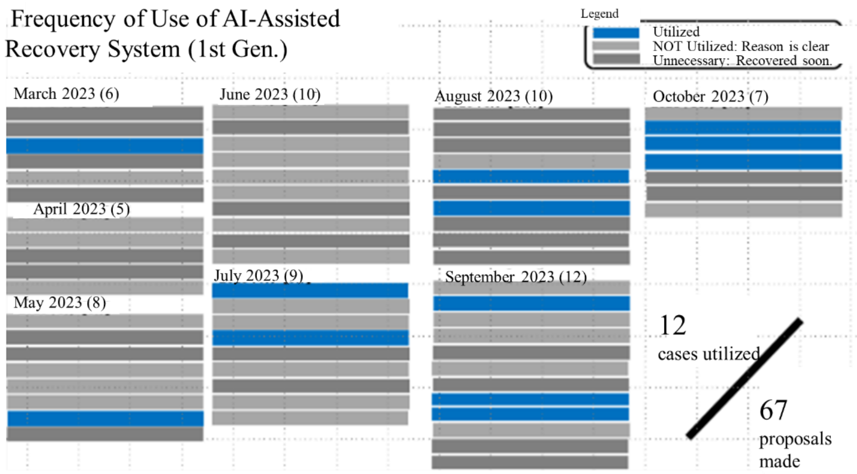

Figure 5: Frequency of Use of the AI-Assisted Recovery System (1st Gen.)

Issue (3): AI Retraining
New failure data is added daily to the Signal and Communication Failure Information Database System.
To train the AI with this new data, the following work is required:

- ✓ Data cleansing performed by staff, as described in Issue (1)
- ✓ Retraining and retuning performed by AI engineers

However, due to limitations in personnel and budget, performing this work every year after system deployment was not feasible.
Therefore, retraining and retuning were scheduled to occur once every five years, and the annual operation was limited to simply adding new cases to the database without retraining the AI.
Furthermore, as AI technology continues to evolve, retraining and retuning become necessary not only to improve accuracy but also when upgrading outdated AI versions for security reasons. This presented an additional challenge.
However, with this operational approach, it would be difficult to prevent the recurrence of failures that cause significant operational impact, especially when rapid retraining is needed immediately after such incidents occur.
For this reason, there emerged a need to explore either a simplified retraining method or an approach that eliminates the need for AI training altogether.

4.2 Adoption of Generative AI

In the AI-Assisted Recovery System (1st Gen.), a pre-trained Large Language Model (LLM)—a precursor to modern generative AI—was selected for natural language understanding, which significantly reduced the workload, development time, and costs. However, for the component that searched for similar past failures and proposed potential causes and countermeasures, a conventional machine learning–based AI was used. As a result, it became clear that all of the aforementioned issues originated from this component. To address these challenges, we began exploring approaches that leveraged the generative AI technologies that emerged in November 2022. We call it “the AI-Assisted Recovery System (2nd Gen.).”
We initially adopted a policy of not performing any additional training on the AI-Assisted Recovery System (2nd Gen.). This system provided in a highly pre-trained state, and as of 2023—when we were examining the system—the functions for fine-tuning the AI-Assisted Recovery System (2nd Gen.) with individual operational events were not yet sufficiently mature. For this reason, we chose this approach. Consequently, the number of failure cases we could utilize expanded from approximately 3,000—limited by cost-performance considerations in machine-learning-based training—to the full dataset of 210,000 cases. Furthermore, because the failure history is stored directly within the searchable scope of the AI-Assisted Recovery System (2nd Gen.), newly occurring failure records can be utilized in real time without requiring any manual work by employees or AI engineers【Issue (1)】.

Next, to increase the frequency of the AI-Assisted Recovery System (2nd Gen.) utilization in actual operations, we conducted a renewed analysis of the OCC work processes associated with equipment failure recovery (Figure 7).

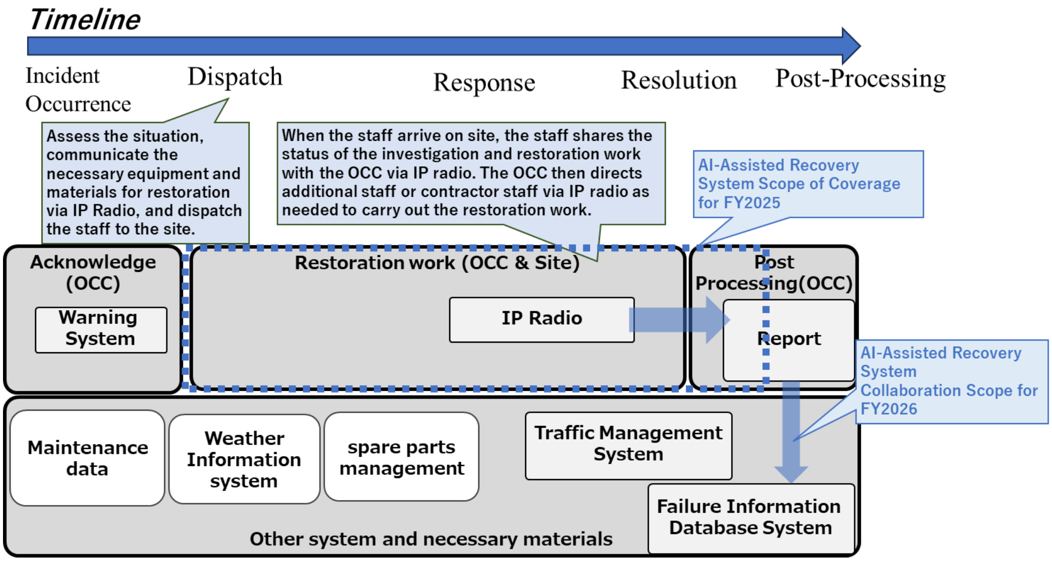

Figure 7: OCC work process associated with equipment failure recovery.

As a result of this analysis, it became clear that the majority of operational tasks were being performed through communications via IP radios. Specifically, a considerable amount of time was spent on the process in which operators would jot down notes on paper based on IP radio conversations and then later type these notes into a cloud-based file for official recordkeeping. This process was carried out at every stage of the response workflow. To address this, we implemented a mechanism using the AI-Assisted Recovery System (2nd Gen.) that automatically converts IP radio audio into text and subsequently summarizes the content at the level of detail required for recordkeeping and report creation, generating a time-series sequence of events【Issue (2)】.

During implementation, it became evident that certain terms specific to signalling equipment, as well as expressions commonly used by signalling personnel, were prone to incorrect transcription and could not be handled adequately by the pre-trained generative AI. To resolve this issue, we created a glossary of signalling terminology and a list of commonly misrecognized words, and configured the AI-Assisted Recovery System (2nd Gen.) to reference these resources during the transcription process. By adopting a reference-based approach—rather than fine-tuning the generative AI with failure history data—we ensured that system functionality would remain compatible with future upgrades of the AI-Assisted Recovery System (2nd Gen.) without requiring additional training work, thereby preventing the emergence of new training-related issues【Issue (3)】.

Finally, in addition to storing failure information and materials used for IP radio transcription, we placed equipment manuals and recovery manuals prepared by operators in the same repository. This enabled the AI-Assisted Recovery System (2nd

Gen.) to propose possible causes and countermeasures based on the content described in these documents. Furthermore, we implemented features that align with the strengths of the 2nd Generation System, including automated report generation, registration of failure information into the Signal and Communication Control Failure Information Database System, and the creation of e-mail drafts used to communicate progress to relevant parties during recovery. We also implemented a function that estimates the expected recovery time based on past cases. By eliminating the need for operators to manually search for these materials, the system provided a clear reason for operators to adopt it and contributed to a significant increase in its utilization rate 【Issue (2)】.

4.3 Practical Implementation (December 2025 –)

By introducing an approach that leverages generative AI and modifying the operational workflow from the 1st Generation to the 2nd Generation (Figure 9), we eliminated all tasks related to training the AI model. At the same time, we established a mechanism that allows the AI-Assisted Recovery System (2nd Gen.) to support a significantly larger portion of OCC workload. Through this redesign, we resolved the issues associated with horizontal deployment and system operation.
As a result, the AI-Assisted Command System was successfully launched in the Shinkansen OCC in December 2025, and in the Tohoku Regional OCC in March 2026. For these deployments, the only preparation required was to collect existing failure records, equipment manuals, and recovery procedures in October 2025, followed by trial operation beginning in November 2025. Because data cleansing and AI training were completely unnecessary, the system could be put into practical operation after only one to four months of operational tuning. A detailed evaluation of the specific effects is currently underway.

5 Conclusions

Expectations are high that reducing the workload of OCC staff and enabling the system to provide more appropriate recommendations will lead to further reductions in recovery time. As a result, numerous requests for horizontal deployment have already been received—from other OCCs within the company as well as from other railway operators. In response, preparations are currently underway to address security requirements and operational arrangements.
Looking ahead, we aim to explore various enhancements that further expand the functions of the AI-Assisted Recovery System by leveraging AI technologies. Several examples of potential future developments are listed below:

- ✓ Automatically ingesting alerts from remote monitoring devices to accelerate OCC staff initial response actions and further shorten recovery times.
- ✓ Incorporating weather data—such as temperature, precipitation, and climate conditions—into the AI-Assisted Recovery System to reduce incorrect recommendations. Currently, the system suggests the most similar past case

regardless of season, which can lead to inappropriate proposals (e.g., suggesting snow-related causes during summer).

- ✓ Integrating with the Tokyo Metropolitan Area Traffic Management System to enhance early cause identification and recovery planning during traffic management disruptions. This would enable automatic dissemination of estimated recovery times to stations for passenger communication.
- ✓ Providing a "prescription for recovery" tailored for field technicians by presenting the required materials, tools, and inspection checklists together with the recommended recovery procedures.

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References

[1] Ikegame, J.: Signal and Communication Command Failure Information Database System, Railway and Electrical Engineering, Vol. 29, No. 7, pp. 22–28, 2018.

[2] East Japan Railway Company (JR East): Initiatives to Enhance Transport Stability Using AI in Signalling Equipment (Press Release, 2022-11-08). https://www.jreast.co.jp/press/2022/20221108_ho01.pdf

[3] East Japan Railway Company (JR East): Promoting DX in Railway Signalling Systems (Press Release, 2024-02-06). https://www.jreast.co.jp/press/2023/20240206_ho03.pdf

[4] East Japan Railway Company (JR East): Applying "Railway-Specific Generative AI" to Signalling and Communication Equipment (Press Release, 2025-06-10). https://www.jreast.co.jp/press/2025/20250610_ho02.pdf

[5] Introduction Material for the Infrastructure Maintenance Award – Excellence Award: AI-Based Recovery Support System for Railway Signal System Failures (Award Summary).