Republic of Türkiye

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Data Collection Survey on Development of Disaster Prevention Capability for Railways in Türkiye
Final Report

May 2025

Japan International Cooperation Agency (JICA)

Japan International Consultants for Transportation Co., Ltd.
East Japan Railway Company
Nippon Koei Co., Ltd.

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25-088

Executive Summary

Chapter 1 Background, Objective, and Methodologies of the Survey

1.1 Background of the Survey

JICA dispatched an international emergency team following the damage caused by the Turkey-Syrian earthquake in February 2023. JICA confirmed that Turkish State Railways (TCDD) had requested technical assistance to restore railway civil structures. Subsequently, JICA, Japan Consultants (JIC) and East Japan Railway (JR East) conducted a field survey in May 2023 and provided consultation on the restoration policy for the damaged sections.

The survey results revealed the necessity to develop disaster prevention standards and system, the need to introduce Japanese railway disaster prevention technology and technical assistance, and the potential for Japanese private sector participation. Based on these findings, JICA decided to conduct the Survey to examine solutions to issues and future development of cooperation to strengthen TCDD's disaster prevention functions Survey on the restoration of railway structures.

1.2 Objective of the Survey

The objectives of the Survey were as follows: 1) Survey on organizing the Natural Disaster Prevention System for railway (including pilot demonstrations); 2) Survey of standards on railway natural disaster prevention and 3) Survey on the restoration of railway structures.

1.3 Schedule of the Survey

The Survey started in December 2023 and ended on 30 June 2025. JST mobilized experts to Türkiye six times. JST interviews with relevant organizations and researched on-site to select the on-site demonstration locations. The demonstration experiment was conducted from January 2025 to the end of May 2025.

1.4 Current status of TCDD

Türkiye's railway network, excluding urban rail, was first established in 1858. Initially developed with foreign investments, the network was nationalized in 1927. As of 2025, it comprises high-speed railways adhering to European standards and conventional railways, including non-electrified sections. The Turkish State Railways (TCDD) operates under the Ministry of Transport and Infrastructure, which oversees transport-related matters. Rail transport accounts for 2.7% of passenger traffic and 4.5% of freight traffic in terms of mode share within Türkiye's transport sector as of 2020.

1.5 Overview of the Urban Railway System in Türkiye

5 cities in Türkiye have a metro system (underground railway), Istanbul, Ankara, Brusa, İzmir, and Adana as of April 2024. Istanbul, Ankara, and İzmir have suburban commuter lines. JST surveyed the overview of the Ankara and Istanbul metro systems in this chapter for benchmarking with TCDD and urban railway systems.

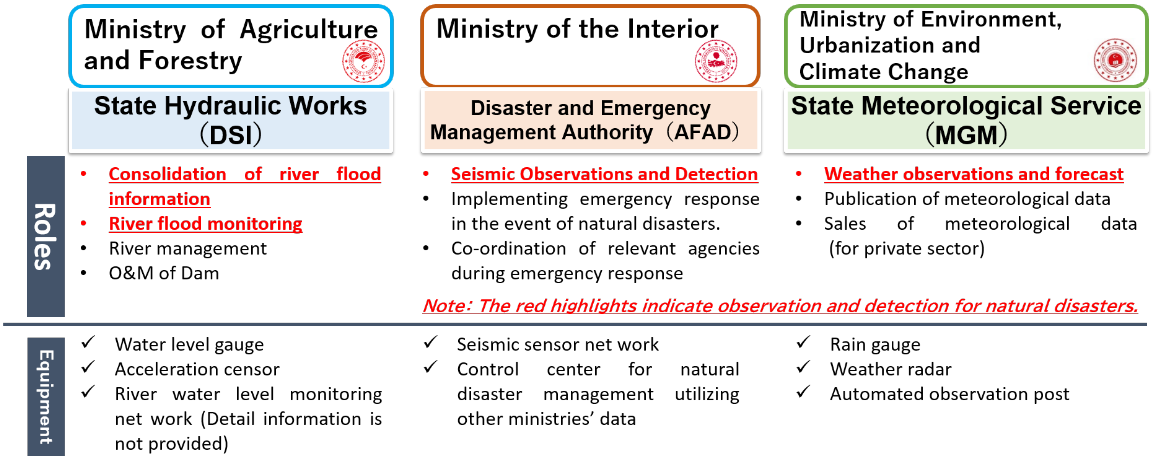
1.6 Review of Assistance Provided by Donors Other Than Japan

"JST was unable to confirm whether any international organizations, including the World Bank (WB), United Nations Development Programme (UNDP), or other donors, have recommended support for railway rehabilitation in relation to the Earthquake. However, it was verified that the WB, AIIB, and IsDB are co-financing a project to rehabilitate an existing railway line from the Georgian border through

Sivas to establish a freight route to Europe. Notably, a component involving an early detection and warning system for natural disaster was initially considered for the project but was later excluded due to uncertainties regarding the return on investment and the WB's indecision.

1.7 Current Status of Natural Disaster Observation Networks in Türkiye

In Türkiye, some government agencies or ministries are responsible for observing and detecting weather-related disasters, earthquakes, and other natural hazards. These entities have established a basic monitoring network. On the other hand, it has been confirmed that those detection networks are not utilized for railway O&M of railway.



Source: JST

Figure 1 Natural Disaster Monitoring System and Relevant Ministries in Türkiye

Chapter 2 Identification of Disaster Risks Close to the Railway

2.1 Natural Disaster Risks in Türkiye

JST studied past surveys and other information on the risks of generating natural disasters in Türkiye. According to Turkish Government statistics, earthquakes, landslides, floods, and rock falls account for more than 90% of buildings that have collapsed due to natural disasters in the past. According to statistics from the Turkish State Meteorological Service (MGM), 1,032 and 1,475 weather-related disasters occurred in Türkiye in 2022 and 2023, respectively, and the number of disasters is increasing in recent years. Of these, heavy rain and floods accounted for 30 to 40%.

2.2 Disaster Risk Screening for the Demonstration Test

During the 1st mobilization of JST in February 2024, discussions with TCDD revealed that landslides and flooding due to heavy rain are frequent. It was confirmed that the priority disasters to address in the building of the railway disaster prevention system are landslides, rockfall disasters, and track flooding.

In coordination with TCDD, the Karabük-Filyos section in northern Türkiye, where heavy rain and rockfall disasters are frequent, was selected for the on-site demonstration. A site visit confirmed that although structural measures such as rockfall protection works and rockfall protection nets have been implemented, there are limitations to structural measures due to budget constraints, and the potential for utilizing railway disaster prevention systems, such as sensors, has been confirmed.

Based on an additional request from TCDD, the on-site demonstration was also conducted in the high-speed railway section in Konya and Karaman regions, where the risk of sinkholes is increasing. In Konya and Karaman provinces, the number of sinkholes has been increasing in recent years, and the areas where they occur are also expanding. Therefore, there are concerns about the occurrence of sinkholes along the high-speed railway tracks.

2.3 Railway Accidents Caused by Natural Disasters in the Past

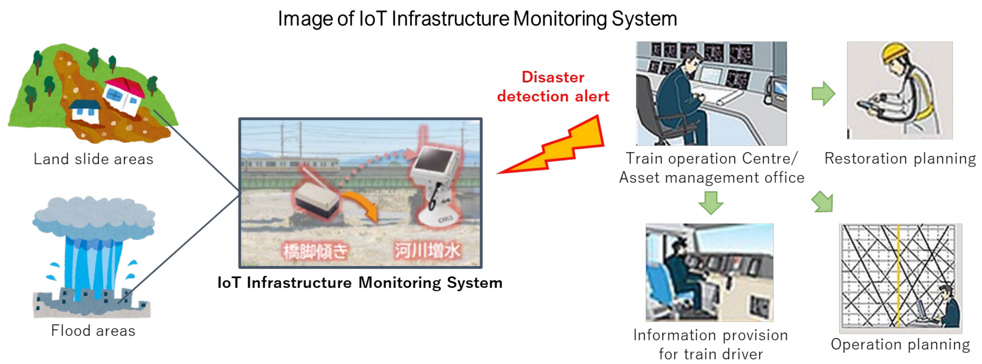
JST identified rail accidents caused by natural disasters which have occurred in Türkiye in the past. According to data from the UEIM, two railway accidents have occurred in Türkiye since 2015 due to natural disasters. However, these are the only events defined as railway accidents, and the UEIM commented that the number of near-miss cases is likely to increase further.

The cases were a derailment due to a rock fall and a derailment due to a roadbed washout. The case suggests that falling rocks and flooding are already an apparent risk in Türkiye.

Chapter 3 Considerations for Implementing the Disaster Management/prevention Systems

3.1 Scope of the Disaster Management/Prevention Systems

JR East has installed a disaster prevention information system (hereafter referred to as PreDAS) as a disaster prevention system. This system transmits data from disaster prevention observation equipment such as seismometers, anemometers, and rockfall detectors installed along railway lines to the command center, and issues speed restrictions and service suspensions and sounds alarms. It is also possible to manage the inspection work of track facilities and civil engineering facilities after restrictions are issued. However, since it is difficult to build the system as it is in this study, a simpler system was adopted. This system is powered by batteries or solar power generation and supports data transmission via wireless network, eliminating the need for power sources and wiring, ensuring ease of introduction. In addition, the system must have sufficient performance in measuring slopes and water levels and taking images, be environmentally resistant to long-term operation even in outdoor fields, and be highly reliable, such as stable operation. The configuration diagram of the system to be introduced in this study is shown in Figure 2.



Source: JST

Figure 2 Configuration Diagram of the Natural Disaster Prevention System to Be Installed In This Survey

3.2 Technical Specification of the System

In this Survey, we will introduce a railway natural disaster prevention system (NDPS) to prevent landslides, rockfall disasters, and river flooding caused by heavy rain. Appropriate specifications were specified and equipment was selected to build the system. Three types of equipment were used: an acceleration sensor, a high-sensitivity camera, and an ultrasonic water level measurement device.

3.3 Challenges for introduction of disaster prevention system

TCDD has no experience in operating an NDPS, so the development of standards will be an issue. The following points should be taken into consideration for drafting the guidelines.

- Development of standards such as railway operation regulation guidelines
- Information about the structure, such as the loss of the design drawing of the structure
- Information about the surrounding environment such as geology
- Selection/establishment of a technical review body

Chapter 4 On-site Demonstration of the Disaster Monitoring/Alert System on the Operating Line in TCDD

4.1 Target

4.1.1 Slope Collapse Detection

Fixed cameras for visual inspection and multiple acceleration sensors are installed on slopes with a risk of rockfall or landslides. If the acceleration sensor detects an abnormality beyond a certain value (threshold), it issues a warning (alert) to the management point. At the same time, the communication frequency is increased to a preset number of times (for example, from once an hour under normal circumstances to once every five minutes).

4.1.2 River Water Level Detection

Railway flood prevention systems, like those that detect rock falls and slope collapses, are equipped with fixed cameras for visual inspection, as well as water level gauges that measure water level on culverts and bridge piers. If the water level gauge detects an abnormality by exceeding a certain value (threshold), it issues a warning (alert) to the management point. At the same time, it increases the frequency of communication to a preset number of times (for example, from once an hour under normal circumstances to once every five minutes).

4.1.3 Sinkhole Occurrence Detection

Fixed cameras for visual confirmation (e.g. taking still images every six hours under normal circumstances) and multiple acceleration sensors are installed along the tracks where there is a high risk of sinkholes occurring. As with slope collapse detection, if the acceleration sensor detects an abnormality beyond a certain value (threshold), it will issue a warning (alert) to the management point. At the same time, the communication frequency is increased to a preset number of times (e.g. from once an hour under normal circumstances to once every five minutes). This also makes it possible to share the display terminal.

4.2 Selection of On-Site Demonstration Area

In this study, demonstration experiments were carried out on the Karabük-Filyos section, where disaster screening was carried out, and on the Ankara-Karaman section (high-speed railway line).

4.3 On-Site Demonstration Plan

Together with the maintenance team from the TCDD local office, we inspected the target section, identified candidate locations that were deemed high risk and would be most effective for monitoring, and analyzed and examined domestically while also conducting detailed on-site surveys and communication tests at 25 locations. As a result, we selected the following eight locations.

Table 1 List of Demonstration Sites

No.	Target structure	Type of disaster	Section	Signaling	Workability
6	Rocking wall 2	Rockfall	Bolkuş-Balıkısık	High	High
9	Cut slope	Landslide	Gökçebey-Üçburgu	High	High
15	Culvert (middle)	Track flooding	Üçburgu- Bakacakkadı	High	High
21	Earthwork 1	Sinkhole	Polatlı-Selçuklu	High	High
22	Embankment slope	Sinkhole	Polatlı-Selçuklu	High	High
23	Earthwork 2	Sinkhole	Kayacık-Meydan	High	High
24	Earthwork 3	Sinkhole	Kaşınhan-Çumra	High	High
25	Earthwork 4	Sinkhole	Çumra-Karaman	Low*	High

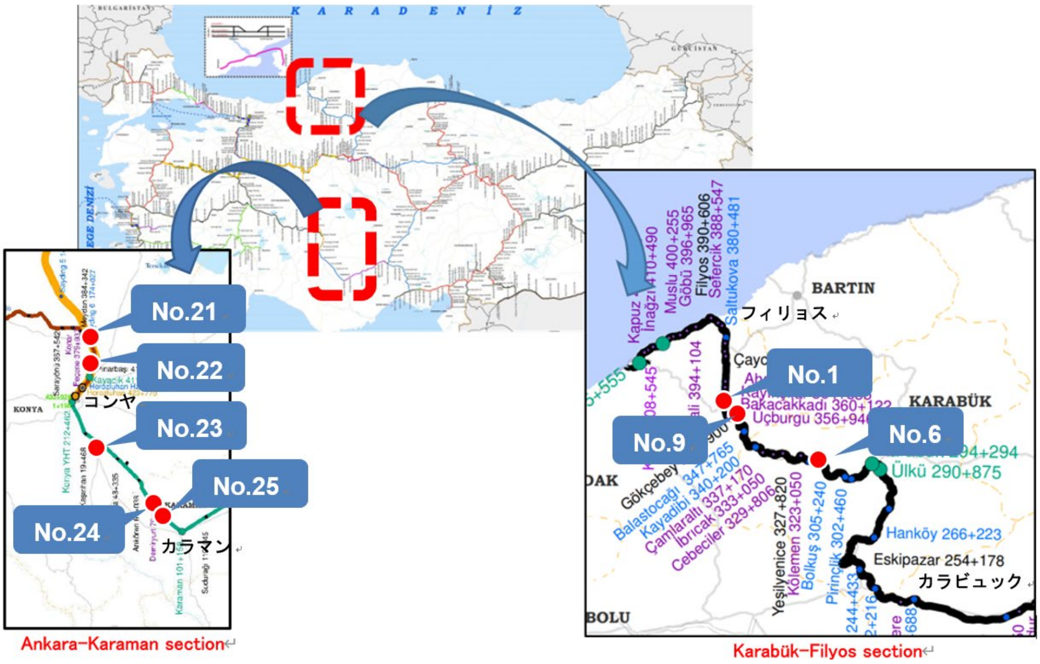
*Based on quick test
Source: JST

4.4 Regulations in Türkiye in the Development of a Railway Disaster Prevention System

In Türkiye, the country is required to comply with the same laws and regulations as EU member states, and devices must comply with these. For example, there are regulations on wireless use, and restrictions on prohibited substances such as RoHS and REACH. Products must be designed and tested to comply with these regulations, and then CE marking must be declared and given the CE mark. In addition, in discussions with TCDD, it was confirmed that a partial exemption from CE marking would be possible by exporting an observation system including cameras and accelerometers, rather than importing individual devices locally. TCDD has already introduced devices from other countries on a trial basis using a similar method.

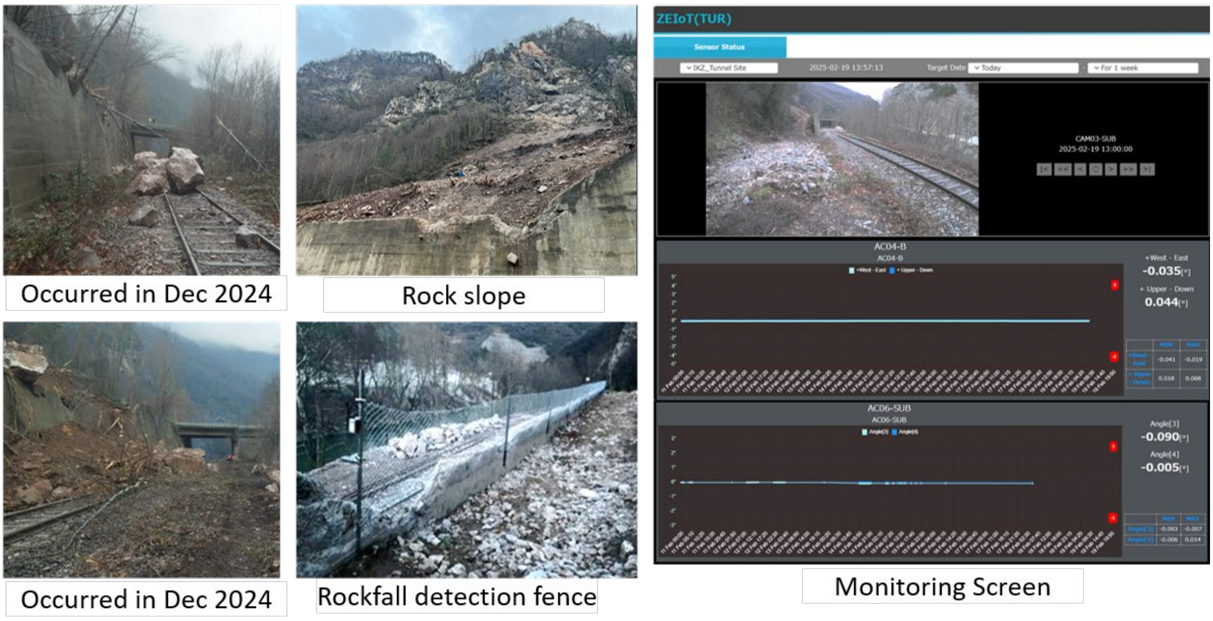
4.5 Result of the On-Site Demonstration

Installation work took place in January and February 2025. TCDD arranged for local workers and equipment, while the study team members fine-tuned the location and installation method, and performed the software setup after the equipment was fixed in place.



Source: JST based on TCDD

Figure 3 Demonstration Sites Map

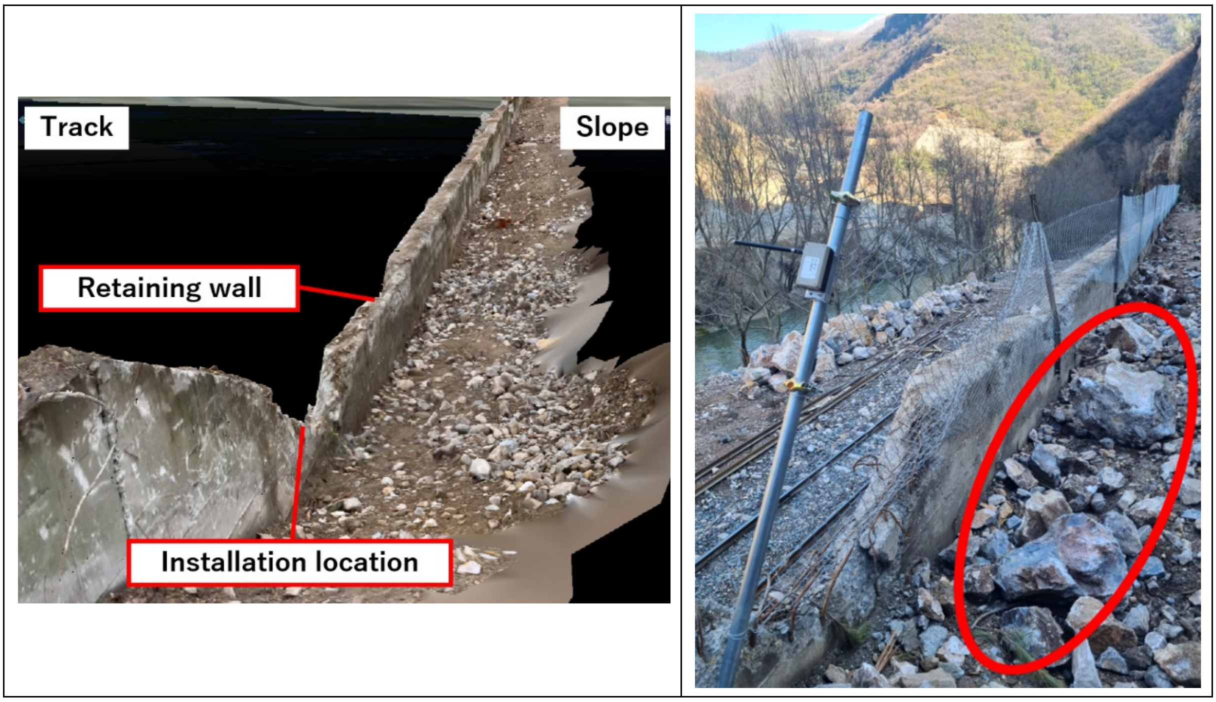


Source: JST

Figure 4 Site Overview and Monitoring (As Example)

4.5.2 Incident Occurred During the Period and JST's Follow-Up for TCDD

At 23:40 (local time) on March 3rd, the accelerometer installed on the No. 6 rockfall detector detected a 22 degree inclination parallel to the track and 6 degrees outward from the track. As a result, there was no impact on the train, but the rockfall itself occurred, proving that the rockfall detection was functioning.



Source: JST and TCDD

Figure 5 Before (Left) and After (Right) the Accident

4.6 Issues Identified Through Demonstration Experiments

The demonstration experiment revealed issues that needed to be resolved before the system could be fully implemented. The four main issues were:

(1) Lack of clear criteria for setting thresholds
(2) Means of alerting
(3) Lack of initial response system and manuals when an abnormality is detected
(4) Poor construction quality when restoring the detection device

Chapter 5 Analysis of Regulations in Türkiye Relevant to the Disaster Prevention Assuming the Future Development

5.1 Legislation Related to the Disaster Management (National Level)

In Türkiye, the Disaster and Emergency Management Authority (AFAD) serves as the core institution for disaster risk management. AFAD was established in 2009 under the Ministry of Interior, following the lessons learned from the 1999 Marmara Earthquake. At the national level, the “Supreme Council for Disaster and Emergency Management,” chaired by the President, and the “Disaster and Emergency Coordination Board,” comprising representatives from relevant ministries, have been established, with AFAD acting as the secretariat for both bodies.

At the provincial level, disaster risk reduction plans known as IRAP (Local Disaster Risk Reduction Plans) have been developed in all 81 provinces, based on a model provided by AFAD. The IRAP formulation process has also benefited from past cooperation with JICA. While IRAP encourages participation from a wide range of stakeholders, including local governments, private sectors, and academia, there remain challenges concerning the absence of legal enforceability and secured budget allocations. Since 2024, efforts have been underway to establish dedicated "Disaster Affairs

Departments" in 30 metropolitan municipalities, aiming to build a municipality-led disaster management system independent of AFAD. However, the organizational structure and operational details are still under development, and direct financial support from AFAD remains limited.

Türkiye's disaster-related plans, formulated by AFAD based on the National Development Plan, consist of the following four pillars. These plans reflect the priorities of the Sendai Framework for Disaster Risk Reduction (2015–2030), with TARAP providing detailed goals and action plans tailored to specific hazard types.

Table 2 Overview of National Disaster Plans in Türkiye

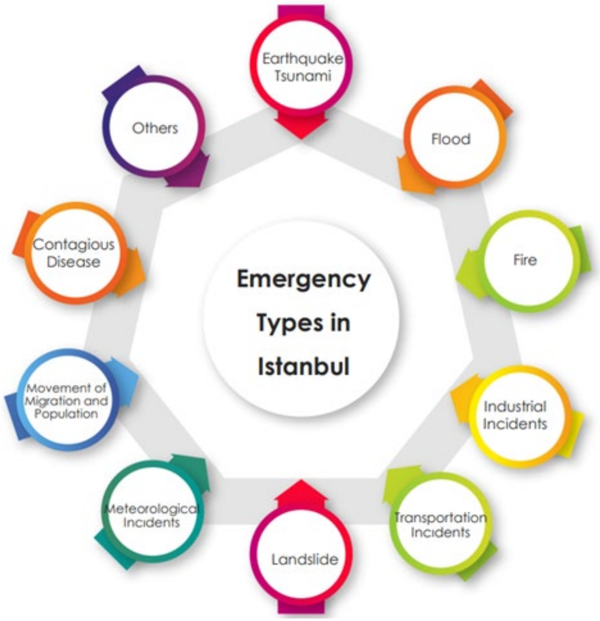
Plan Name	Overview
TAYS (Disaster Management Strategy Document)	Presents the basic vision for national disaster management (Enforced in 2017)
TARAP (Disaster Risk Reduction Plan)	Medium- to long-term plan aiming to minimize disaster risks (Target period: 2022–2030)
TAMP (Disaster Response Plan)	Specifies the roles and response policies of each organization during disaster occurrence (First issued in 2014, revised in 2022)
TASIP (Disaster Recovery Plan)	Aims to expedite and enhance disaster recovery (Announced in 2023)

Source: Compiled by the JICA Survey Team based on information from the AFAD website.

5.2 Survey of Japanese Railway Disaster Prevention Legislation and Standards

In Japan, railway operators formulate and implement detailed work plans, operate railways and command manufacturers, construction companies and others based on licences granted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The railway operator is legally responsible for all aspects of the railway, from construction to operation, and the condition for a business licence is that the railway operator is competent to carry out these tasks on its own. In addition, the performance and operational methods to be provided by railway facilities are stipulated in ministerial ordinances, interpretation standards and implementation standards, and actual railway facilities are designed, constructed and operated in accordance with these regulations and domestic standards such as JIS.

In principle, the railway facility owner (in most cases, the railway operator) bears the cost of restoration work and restoration costs in the event of natural disasters such as earthquakes, heavy rain, strong winds and heavy snowfall, as well as disaster prevention and disaster mitigation measures. In the circumstances where damage to railway facilities has increased and become more severe due to the recent spate of natural disasters, MLIT issued the 'Measures for Railway Disaster Prevention and Mitigation' in 2008 in order to further improve railway disaster prevention and mitigation measures from the user's perspective, including early restoration of railway facilities. Based on this policy, subsidies related to disaster prevention and disaster mitigation measures were set out in the subsidies for the cost of comprehensive safety measures for railway facilities, and subsidies for the cost of measures against flooding, heavy rain, earthquake resistance, ageing railway facilities, etc. and for the cost of disaster recovery of railway facilities were realized according to the importance of the route and the size of the operator.



Source: Metro Istanbul

Figure 6 Emergency Types in Istanbul

5.3 Survey of Turkish Railway Disaster Prevention Legislation and Standards

In Türkiye, the Directorate General for Service Regulation UDHGM of the MOT is responsible for inter-city railways, i.e. the TCDD Group, while the Railway Transport Authority within UHDGM is responsible for railway operations and the Railway Certification Authority for technical matters, TCDD owns and manages the rail facilities in accordance with the technical standards set by the Railway Certification Authority; TCDD Transport is responsible for rolling stock and operations and pays TCDD a fee for the use of the facilities.

TCDD is not incorporated into AFAD's disaster management plan and implements its own disaster management measures. Sensors for rainfall, seismic intensity, etc. are maintained by TCDD and are not linked to data from other agencies such as MGM. In the event of a disaster, TCDD is responsible for restoring railway facilities with its own funds; during the major earthquake of 2023, restoration costs were allocated to TCDD via the MOT through budgetary measures based on the declaration of a state of national emergency in Türkiye.

On the other hand, urban railways in Ankara, Istanbul and other cities are not under the jurisdiction of the MOT, as they are part of the metropolitan area municipalities and their railway facilities and operations are integrated. The technical standards for the railways are set by the respective metropolitan municipality, but the technical content is reported to the Railway Certification Authority.

Disaster preparedness for urban railways is carried out jointly with the non-railway sections of metropolitan municipalities, in cooperation with AFAD and the metropolitan municipal disaster coordination centre AKOM. Sensors for rainfall, earthquakes, etc., installed at the expense of metropolitan municipalities are used jointly by the sections, and MGM information is also used. Disaster recovery costs are borne by the metropolitan municipalities.

In both Ankara and Istanbul, scenarios and response measures for various emergency situations, including natural disasters and other contagious diseases and industrial accidents, have been thoroughly studied from the time of railway planning. Disaster response manuals are in place and regular drills are conducted. In terms of hardware measures against natural disasters, earthquake-resistant structures are applied throughout both cities, and measures are in place to prevent flooding due to heavy rainfall, etc. For fire protection, the US NFPA 130 is applied.

5.4 Issues Related to the Development of Laws and Regulations

Disaster administration in Türkiye is centrally managed by AFAD, with TARAP (Disaster Risk Reduction Plan) positioned at the national level and IRAP (Local Disaster Risk Reduction Plan) at the provincial level. In addition, TASIP (Disaster Recovery Plan) has been developed to provide direction for post-disaster recovery.

IRAP emphasizes hazard analysis for each disaster type and incorporates a wide range of measures involving many stakeholders. However, the lack of legal enforceability and budgetary backing presents significant challenges. Consequently, the implementation of disaster risk reduction measures based on IRAP has been limited. Centralized formulation and implementation of plans by the national government for local authorities has been criticized as inefficient. Moving forward, legal reforms mandating the formulation of local government-led plans and the enhancement of municipal capacity are required. Following the earthquake in February 2023, interest in disaster risk reduction has grown significantly. Türkiye's 12th National Development Plan emphasizes the revision of IRAP, preparedness for large-scale disasters, the strengthening of urban and infrastructure resilience, and the review of the legal framework.

Thus, disaster administration at the national level in Türkiye has steadily developed both its legal and organizational framework, centering on AFAD. For example, urban railways such as Ankara Metro and Metro Istanbul are integrated into the disaster response system of metropolitan municipalities, with clear roles assigned according to the scale and nature of disasters. In contrast, TCDD (Turkish State Railways) operates outside the national disaster response framework and is required to independently handle all disaster-related processes from detection to recovery.

Chapter 6 Status of Railway Restoration and Issues at Sites

6.1 Restoration Status of the Railway Civil Structures Damaged by the Earthquake

On 6 February 2023, at 4:17 and 13:24, earthquakes occurred in southeastern Türkiye due to the lateral movement of the Anatolian Fault. The total length of the railway lines affected was 1,275 km, and there were significant displacements of the tracks

The line connecting İslahiye, Fevzipaşa, Narlı, Gölbaşı and Malatya runs along the Anatolian Fault, and due to landslides, falling rocks, damage to bridges and collapsing tunnels, it was not possible to resume operations on the entire line.

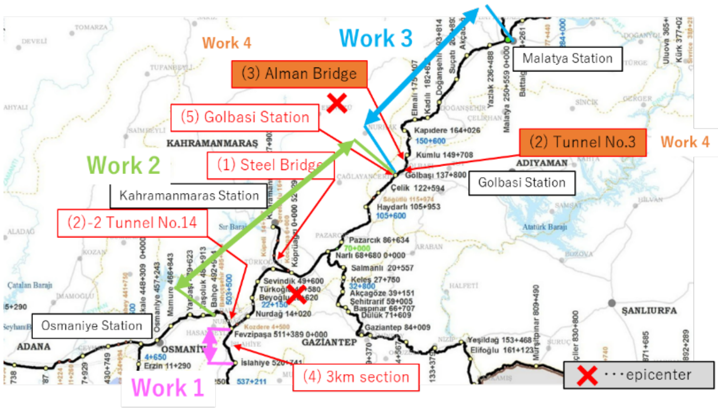


Figure 7 Work Packages (Work 1-4), Civil Structures

Source: TCDD

TCDD had no experience of large-scale damage to civil structures occurring at multiple locations, so TCDD sought advice from Japan on the restoration plan for the structures. In response, a survey team including engineers from JR East conducted a site survey and discussed the plans. The restoration plans by Turkish engineers were also acceptable to Japanese engineers. The Japanese side provided advice on countermeasures against liquefaction and falling rocks (survey in May 2023).

This survey investigated the progress of the restoration of the structures that the previous survey team had advised on (February 2024). The construction works were being carried out in accordance with the policy agreed to by the Japanese side in the previous survey. From the state of the RC wrapping of bridge piers and tunnel restoration, it was confirmed that Türkiye had accumulated sufficient design and construction technology. However, there were also construction details that failed to convey the Japanese side's image, such as the anti-slip device installed on the piers of the Alman Bridge.

The tunnel-type rockfall protection measures using corrugated steel plates adopted by TCDD may cause large displacement with relatively small energy in the event of a rockfall. The survey team expressed concern about the plan to support the power lines with corrugated steel plates in electrified sections.

At the site, the restoration of structures has been completed; however, the rehabilitation of the roadbed and other elements remains time-consuming. The line was originally opened in 1935, when structural standards were not clearly defined and do not comply with current regulations. During the restoration process, it has been necessary to renovate the roadbed and other components across the entire line to meet present-day standards.

As of February 2025, restoration work has progressed to 95% completion, and reports have indicated that train operations at Gölbasi are expected to resume by the end of May 2025.

6.2 Issues in the Recovery System

In the initial phase following the earthquake, TCDD conducted inspections of the railway tracks and proceeded with track repairs. Within two weeks after the earthquake, approximately 1,160 km out of the total 1,275 km in the affected section were made operable for vehicles, despite the absence of functional power and signaling systems. This outcome was attributed to the autonomous restoration efforts carried out by regional maintenance departments. However, it cannot be ruled out that certain facilities, which actually required emergency measures, were put into operation without such measures being properly implemented.

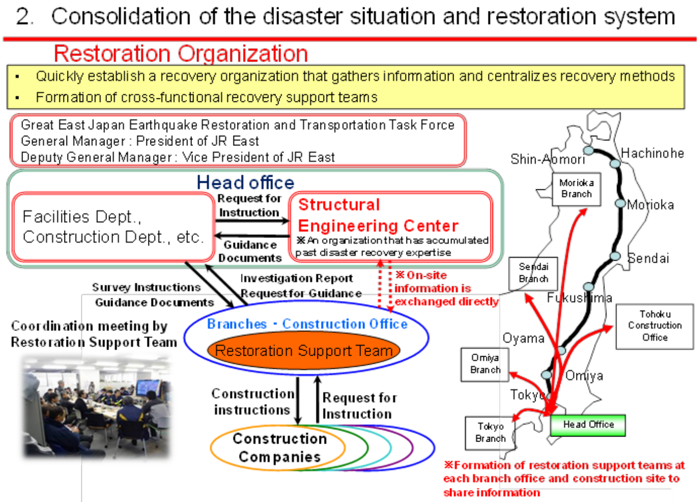


Figure 8 JR East Structure Restoration System

Source: JR East

TCDD is expanding its high-speed rail network, resulting in a significant increase in viaducts and tunnels. With the notable rise in the number of users, the establishment of a swift disaster recovery system is imperative.

If a major earthquake occurs in JR East's area, JR East employees and employees from partner companies begin inspecting and surveying the facilities. The inspections and surveys are carried out using common assessment criteria and under the direction of the branch office restoration support team in the affected area. The information gathered is sent centrally to the technical department of the head office restoration support team, which makes managerial and technical decisions and gives instructions to the branch office team. As TCDD does not have such a system, JST propose that a system be established based on JR East's system. The key points of the system are as follows.

a.) Technical capabilities based on accumulated experience

It is necessary to establish an organization with high technical capabilities, such as the Structural Engineering Centre of JR East, and to accumulate experience in responding to disasters.

b.) Establishing a restoration organization and quickly starting up support team

Quickly starting up support team is necessary not only for the recovery of structures, but also for the utilization of all kinds of information. It is also necessary to hold regular training for assembling.

c.) Early determination of recovery policy

Judgements such as whether to restore temporarily or permanently, depending on the importance of the line, etc., require managerial judgement. Therefore, it is necessary to have a technical department within the head office restoration support team.

d.) Establishing an organization with a clear chain of command

In order to prevent confusion in instructions during a disaster, it is necessary to constantly review the chain of command and introduce the latest communication technology.

e.) Early recovery through cooperation between organizations

In Japan in recent years, road management organizations, river management organizations and railway operators have been working to shorten the overall construction period and reduce costs by examining comprehensive recovery processes.

Chapter 7 Considerations for the Future Improvement

7.1 Existing Issues and Difficulties in Türkiye

Regarding issues related to disaster management systems, not only the TCDD but also the regulator or the relevant authorities have recognized the need to strengthen O&M capabilities. The challenges are the absence of a disaster management system and the lack of an organizational structure that is a prerequisite for utilizing a system. Another challenge is that the existing observation network is not utilized for railway O&M, which the UEIM mentions.

Regarding standards and regulations, some advanced disaster management plans and response policies exist at Türkiye's national and provincial levels. Their legal effectiveness and state of development are limited, and the main focus is on post-disaster response planning. In addition, those plans do not include the perspective of infrastructure disaster management, including railway. As a result, regional authorities and AFAD are at the center of the response framework in the event of a disaster. However, TCDD needs to restore its infrastructure at its own capability. In addition, some urban rail operators have planned disaster responses using quantitative indicators. However, as they are relatively newly constructed rail systems, they have no experience in large-scale disaster recovery, and the adequacy of the criteria for early resumption of operations assuming the network expansion is an issue. It was also found that restoration procedures and financial assistance schemes for railway O&M executors are not yet in place. The restoration work needs to be implemented by local and national government budgets.

Regarding structural restoration, the areas surveyed by the Prior survey team in May 2023 had suffered significant damage to bridges, tunnels, and other structures. As a result of the restoration work conducted by TCDD, it was confirmed that the restoration of the structures was completed or in progress. As the number of structures such as tunnels, bridges, and viaducts increases due to the construction of high-speed railways in the future, the number of structures damaged by the earthquake will also increase. It is estimated that it will be challenging to quickly diagnose damage and formulate restoration policies for many structures in this context.

7.2 Recommendations for Solving Problems

It is necessary to reinforce the infrastructure and implement soft measures as proactive disaster prevention. Furthermore, it is essential to conduct medium- and long-term capacity development, including enhancing the organizational structure (personnel, rules, and mechanisms) to realize these measures for resilience improvement.

Based on the recognition of the issues in this survey, implementation items in the three areas, such as structure reinforcement, implementation of soft measures, and enhancement of the organizational structure, including in the medium and long term, have been summarized.

It is estimated that Turkish companies can implement structure reinforcement, and the participation of Japanese companies is considered to be limited.

Regarding soft measures, it is estimated that Japanese companies can be involved in O&M support as a business, taking advantage of their knowledge and practical experiences.
With regard to enhancing the organizational structure, it is estimated that it is difficult for private companies to participate solely in this area as a business. For this reason, it is possible to consider Japanese private sector participation by using support schemes that include other donors.

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Abbreviations and Terminology

Abbreviation	Terminology (tur: Turkish terminology)
ADB	Asian Development Bank
AFAD	Türkiye Disaster and Emergency Management Authority
AIIB	Asian Infrastructure Investment Bank
AKOM	Disaster Coordination Center of Istanbul Metropolitan Municipality (tur: Afet Koordinasyon Merkezi)
AYGM	General Directorate of Infrastructure Investments (tur: Altyapı Yatırımları Genel Müdürlüğü)
Co.	Company
CTC	Centralized Traffic Control
DF/R	Draft Final Report
DPM	Deputy Project Manager
DSI	State Hydraulic Works (tur: Devlet Su İşleri Genel Müdürlüğü)
EBRD	European Bank for Reconstruction and Development
EN	European Standards (European Norm)
ETCS	European Train Control System
F/R	Final Report
GNSS	Global Navigation Satellite System
IC/R	Inception Report
IsDB	Islamic Development Bank
IT/R	Interim Report
IRAP	Provincial disaster risk mitigation plan (tur: Afet Risk Azaltma Planı)
JBIC	Japan Bank for International Cooperation
JDR	Japan Disaster Relief Team
JETRO	Japan External Trade Organization
JIC	Japan International Consultants for Transportation Co., Ltd.
JICA	Japan International Cooperation Agency
JR East	East Japan Railway Company
JST	Japanese Survey Team
JV	Joint Venture
Ltd.	Limited
MGM	Turkish State Meteorological Service (tur: Meteoroloji Genel Müdürlüğü)
MOT	Ministry of Transport and Infrastructure (tur: Ulaştırma ve Altyapı Bakanlığı)
MoEUCC	Minister of Environment, Urbanisation and Climate Change (tur: Çevre, Şehircilik ve İklim Değişikliği Bakanlığı)
MTA	General Directorate of Mineral Research and Exploration (tur: Maden Tetkik ve Arama Genel Müdürlüğü)
NK	NIPPON KOEI (en.: International Engineering Consultants)

Abbreviation	Terminology (tur: Turkish terminology)
OCC	Operation Control Center
ODA	Official Development Assistance
PM	Project Manager
PreDAS	Prevention of Disaster Alarm System (Comprehensive information management system for disaster monitoring and detection invented by JR East)
TCDD	Turkish State Railways (tur.:Türkiye Cumhuriyeti Devlet Demiryolları)
UEIM	General Directorate of Transportation Servecies Regulation (tur: Ulaştırma Hizmetleri Düzenleme Genel Müdürlüğü)
UHDGM	General Directorate of Transportation Services Regulation (tur: Ulaştırma Hizmetleri Düzenleme Genel Müdürlüğü)
UNDP	United Nations Development Program
WB	World Bank

Chapter 1 Background, Objective, and Methodologies of the Survey

1.1 Background of the Survey

On February 6, 2023, a 7.8 magnitude Türkiye-Syria earthquake (hereinafter referred to as the Türkiye-Syria earthquake) occurred in south-eastern Türkiye. In response to the extensive earthquake damage, the Japan International Cooperation Agency (JICA) dispatched an international emergency relief team and a team of experts in March 2023. The team confirmed that the railway sector's preparedness for earthquake disasters was insufficient. It also confirmed the possibility for providing technical assistance to TCDD (Türkiye Cumhuriyeti Devlet Demiryolları: Turkish State Railways) to restore the railway infrastructure, such as bridges and tunnels.
Subsequently, based on TCDD's request, JICA, JIC, and JRE, which have expertise in the field of earthquake restoration, conducted a consultation on the restoration of the damaged infrastructure between April 30 and May 9, 2023 (hereinafter referred to as the May 2023 Survey) in specific areas where TCDD was facing difficulties in restoring it back to its original condition.
As a result of the May 2023 Survey, JICA received a request from TCDD regarding the establishment of a railway disaster prevention system in preparation for future large-scale disasters, support for the restoration of disaster prevention-related structures and infrastructure in Türkiye in general and TCDD in particular, and the development of disaster prevention-related standards for Türkiye and TCDD to deal with disasters.
In response to these requests, the participants introduced the railway disaster prevention system based on Japanese experiences, the need for continuous technical assistance to strengthen disaster prevention capabilities further, and the potential for business development utilizing the railway disaster prevention technology of Japanese companies.
Based on these findings, it was decided to carry out this Survey in order to examine the current status and the challenges of TCDD and the Turkish railways' disaster prevention functions, to propose improvement measures based on these, and to examine the possibilities for future deployment by Japanese companies and others.

1.2 Objective of the Survey

The purpose of the Survey is to study the following three major items, and to collect basic information in order to consider the cooperative approach necessary for strengthening the disaster prevention capabilities of the railways in Türkiye.
The railway disasters in the Survey refer to damage to railway facilities and impacts on railway operations caused by natural disasters.

Survey on establishment of railway disaster prevention system (including on-site demonstration for monitoring/alert system)

The JICA survey team (hereinafter JST) will survey and analyze risks of railway disasters and collect information in the on-site demonstration area or section. JST will conduct the survey in consideration of a railway disaster prevention system based on the collected information and discussions with TCDD. Related technologies will be introduced to TCDD, along with case studies using Japanese railway disaster prevention technology and services.

Furthermore, the on-site demonstration will be conducted and similar products which are being implemented in Japanese railway operators' natural disaster prevention systems will be used during this on-site demonstration in Türkiye as well. After that, JST will sort out issues, including introducing, operating, and maintaining railway disaster prevention systems, and make proposals that include the necessary business development ideas.

Survey of standards related to railway disaster prevention

JST will study the status of developing laws, standards, systems, and regulations related to railway disaster prevention in Türkiye. JST will propose standards and systems that need to be developed in the future, considering disaster risks in Türkiye.

Advice on the restoration status of structures and infrastructure

JST will survey the restoration status of the structures and infrastructure identified in the May 2023 survey. Furthermore, JST will assess the current status and issues regarding disaster recovery, systems, and restoration policies and provide information and case studies to improve TCDD's restoration work if necessary.

1.3 Schedule of the Survey

The schedule of the Survey was made based on the following schedule, with JST’s members travelling to the field to conduct on-site surveys, as well as conducting desktop surveys and online meetings in Japan.

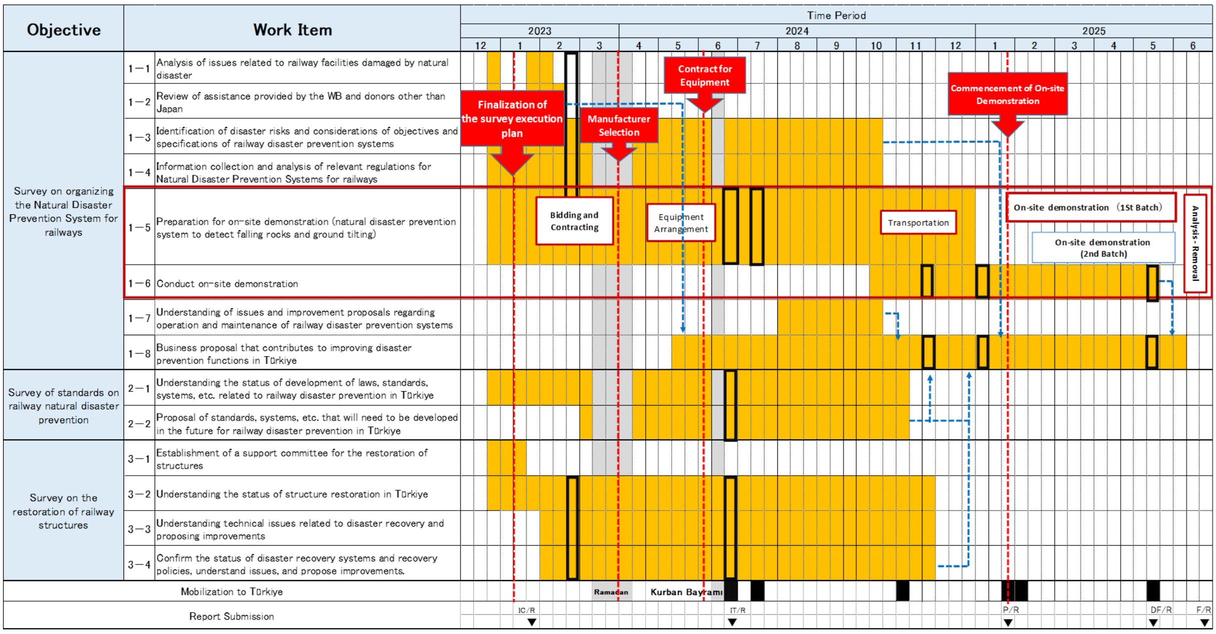


Figure 1-1 Schedule of the Survey

Mobilization took place based on the above schedule. An overview of the mobilization is provided below.

(1) 1st Mobilization (February 14, 2024 to March 2, 2024)

JST conducted on-site surveys for on-site demonstration and structural restoration support.

JST had discussions with TCDD and other contractors about earthquake restoration work; interviews and information gathering were conducted with AYGM (General Directorate of Infrastructure Investments: Altyapı Yatırımları Genel Müdürlüğü) and AFAD (Disaster and Emergency Management Presidency: Afet ve Acil Durum Yönetimi Başkanlığı).

Furthermore, JST also held discussions with JICA Türkiye Office, the Embassy of Japan in Türkiye, the World Bank, JBIC (Japan Bank for International Cooperation), and JETRO (Japan Bank for International Cooperation).

JICA and JST exchanged a memorandum with TCDD on the purpose of the survey, and TCDD's cooperation was confirmed.

In particular, during the discussions with TCDD, other opinions were exchanged, and case studies were introduced for helping TCDD to understand the usefulness and the functions of Japan's disaster prevention systems. In Gaziantep, JST surveyed the restoration status of railway structures and infrastructure in the areas affected by the Turkish-Syrian earthquake. JST discussed the issues relevant to the structural restoration work with TCDD and local contractors and identified them in the context of the current situation.

In Karabük, an on-site survey was conducted to identify hazardous areas and study the planned demonstration site, as an area that was affected by falling rocks.

Source: JST

Figure 1-2 Activities in 1st Mobilization (Left: On-site survey, Right: Sharing session)

(2) 2nd Mobilization (June 23, 2024 to June 29, 2024)

JST interviewed the regulatory authorities: UHDGM (Directorate General of Services Regulation, Ministry of Transport and Infrastructure) and UEIM（Transport Accident Investigation Center: Ulaşım Emniyeti İnceleme Merkezi). JST collected information that was relevant to railway regulations and urban railway matters during the interview. In the interview with the regulatory authorities, JST obtained their opinions on the on-site demonstration to be conducted in this survey, the development of standards related to disaster prevention based on these experiments, and the necessity for Japan's support. UHDGM was interested in the technical standards for Japan's disaster prevention. UEIM indicated a need for support in strengthening organizational structures during the interview.

JST conducted interviews with DSI (State Hydric Works: Devlet Su İşleri Genel Müdürlüğü), MGM (Turkish State Meteorological Service: Meteoroloji Genel Müdürlüğü). This interview intended to grasp existing conditions, including the observation network, the utilization of observation data, and the experience of disaster restoration. Furthermore, JST interviewed urban railway operators in Ankara and Istanbul relevant to the conditions of disaster prevention systems and disaster restoration. The survey items covered the operations and maintenance (O&M) systems. JST shared information on the deployment status of disaster prevention systems in Japanese cable cars in response to an inquiry from Metro Istanbul. Metro Istanbul was particularly interested in the process of making fast decision between Japanese operators, from disaster occurrence to operation management.


Source: JST

Figure 1-3 Discussion During 2nd Mobilization (Left: MGM, Right: UHDGM)

(3) 3rd Mobilization (July 10, 2024 to July 20, 2024)

The objective of third mobilization was to investigate the on-site demonstration sites in detail.
As the demonstration used TurkCell's telecommunication networks, JST conducted communication tests using test equipment provided by TurkCell. The equipment was supplied from TurkCell's testing department and transported to Karabük.
JST conducted communication tests at the locations identified as candidate sites on the first on-site visit. And 360° camera imaging was performed. It was to finalize the installation locations and collect detailed information required for the consideration of installation methods.

(4) 4th Mobilization (November 3, 2024 to November 9, 2024)

During the 4th mobilization, JST conducted discussions to finalize the custom procedures for transporting equipment into Türkiye, clarify responsibilities regarding equipment importation, and confirm the installation schedule for the 1st batch of the on-site demonstration in Karabük.
Additionally, on-site surveys were conducted in the Karabük–Filyos section and the Ankara–Konya high-speed railway section as potential additional sites for the on-site demonstration. These surveys included communication tests and aimed to finalize candidate locations for additional installations.

(5) 5th Mobilization (January 18, 2025 to February 14, 2025)

JST delivered the equipment to the site finalized in the fourth mobilization. Experts set up and installed the equipment and provided training to the relevant staff in cooperation with TCDD.
An on-site demonstration for detecting rock falls and floods was launched in the Karabük district on January 23. Additionally, an on-site demonstration of a system for detecting subsidence and deformations caused by sinkholes was launched in the Konya district on February 6. Experts conducted training on the use and maintenance of the demonstration equipment at the maintenance offices in both districts.
Furthermore, to consider the enhancement of disaster prevention capabilities in the future, the team conducted an interview with SBB (Presidency of Strategy and Budget) and other ministries to confirm the concept of proactive disaster investment in Türkiye.

(6) 6th Mobilization (May 10, 2025 to May 17, 2025)

JST shared the results of the on-site demonstration that started in January 2025 and the findings of this Survey with TCDD's maintenance department. JST also discussed future challenges and prospects for Japanese private sector companies with Türkiye's relevant ministries and agencies.

The final report to the maintenance department of TCDD took place on May 13. The results of the Survey were shared with TCDD officials, including the Head of the Maintenance Department, the managers of the High-Speed Rail Maintenance Department, and other relevant parties, including the Japan Embassy, the JICA Türkiye Office, and the World Bank Ankara Office. The table below shows the participants and the details of the activities.

In addition, JST discussed with AYGM to confirm the AYGM's position on deploying the disaster management system and how the system should be deployed.

Table 1-1 Overview of the Final Report and Participants

Item	Descriptions
Attendees: TCDD	Infrastructure Maintenance Department: Department Head, Deputy Department Head Project Application Branch: Branch Manager Track maintenance Manager, High-speed rail maintenance manager Head of Karaman maintenance office, Manager of Karabük maintenance office
Attendees: Japan International Organizations	Embassy of Japan: Second Secretary and one other local staff member JICA Türkiye Office: Chief Representative and two other staff members World Bank: Transport Specialist
Contents	1. Result of Survey 2. Japanese operators' practices (JR East) on Disaster Prevention and regular maintenance 3. Natural disaster restoration work in Japan 4. Reccomendations
Q&A	• Regulations on the location of railway rain gauges, spacing and location. • Methods for dealing with flooding close to the railway tracks due to precipitation far from track • Based on the case of bridge flooding, how far in advance of a disaster is it known and warnings received • Cases of bridge damage introduced, strengthening of bridges and piers, and implementation of structural measures • Liability of railway operators in the event of accidents caused by natural disasters in Japan

Item	Descriptions
	• The budget spent on railway disaster prevention in Japan • How to respond in the event of an earthquake in Japan, based on the Marmara Sea earthquake (M6.1) • How to determine reference values for operation and maintenance decisions, based on actual data from Türkiye,

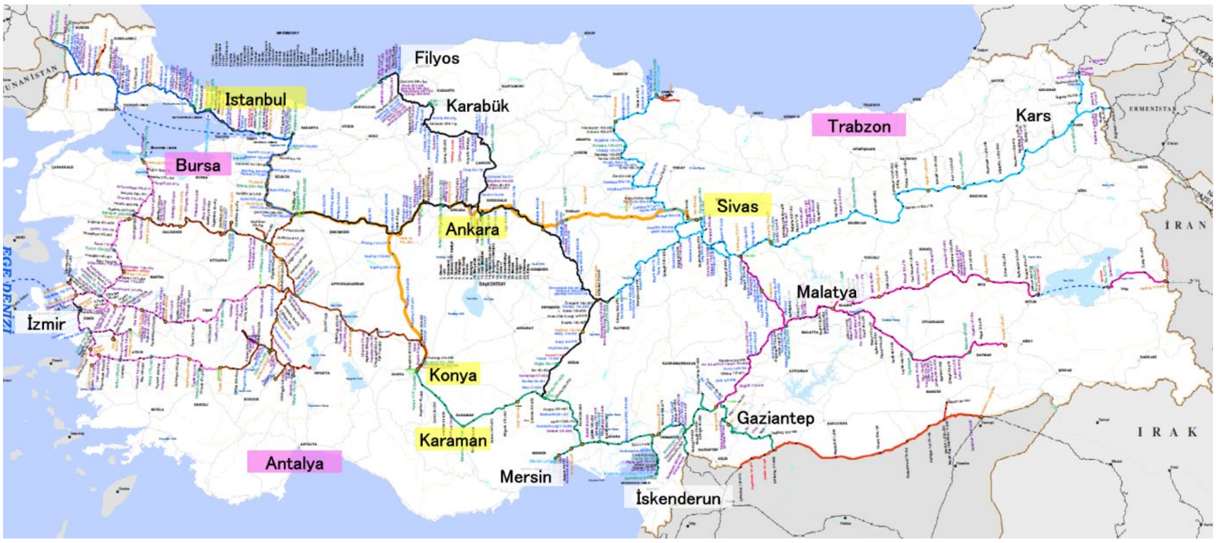
Source: JST

1.4 Current Status of TCDD

The development of Türkiye's railway network began with the Izmir-Aydin line, which opened in 1858. It was built with the aim of carrying transport between the Middle East and Europe with the investment of foreign capital.

The existing intercity rail network does not always cover the city center of major cities. In addition, there are many sections where the alignment and natural environment are challenging to the operation of the railway. TCDD's existing railway network is shown below (Figure 1-4).

It can be seen that the railway does not pass through the major cities on the Black Sea coast, such as Trabzon, Ordu, Antalya on the Aegean Sea coast, and the city of Bursa near Istanbul.



Note: The origins and terminus of high-speed rail lines are shown in yellow, and major cities that are not served by rail lines are shown in pink.

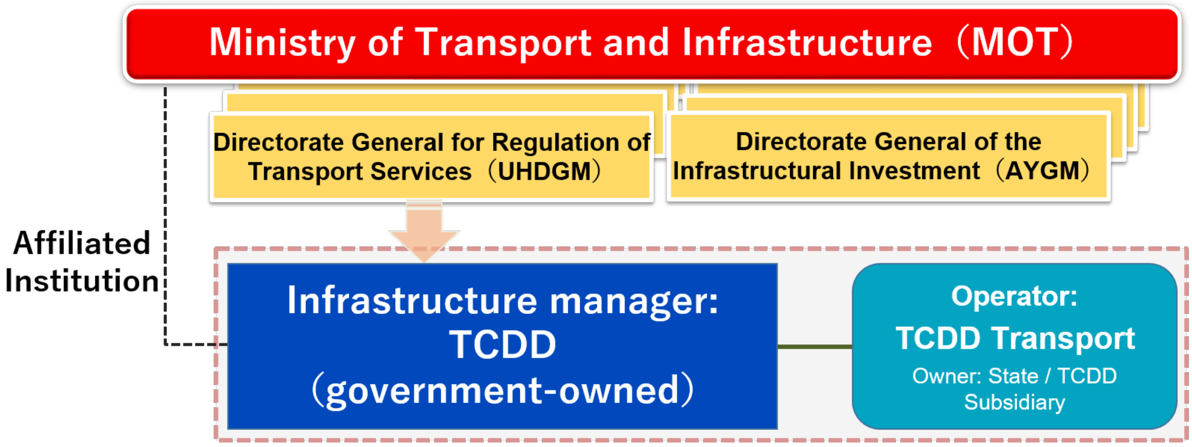
Source: JST added the name of cities on TCDD's material

Figure 1-4 TCDD's Railway Network

Türkiye's intercity rail network was nationalized in 1927, bringing together the rail networks built with foreign capital and state-owned railways built by the Ottoman Empire.

Today, TCDD is still a state-owned company under the control of the MOT (Ministry of Transport and Infrastructure). TCDD acts as the infrastructure manager for conventional and high-speed rail lines and is responsible for the maintenance and operation of facilities. The positioning of TCDD and MOT is shown in the figure below (Figure 1-5).

MOT, which is responsible for the supervision of transport-related matters, includes 20 directoratesgeneral and eight affiliated institutions. TCDD, as an affiliated institution, is subordinate to the Ministry of Transport and Infrastructure.



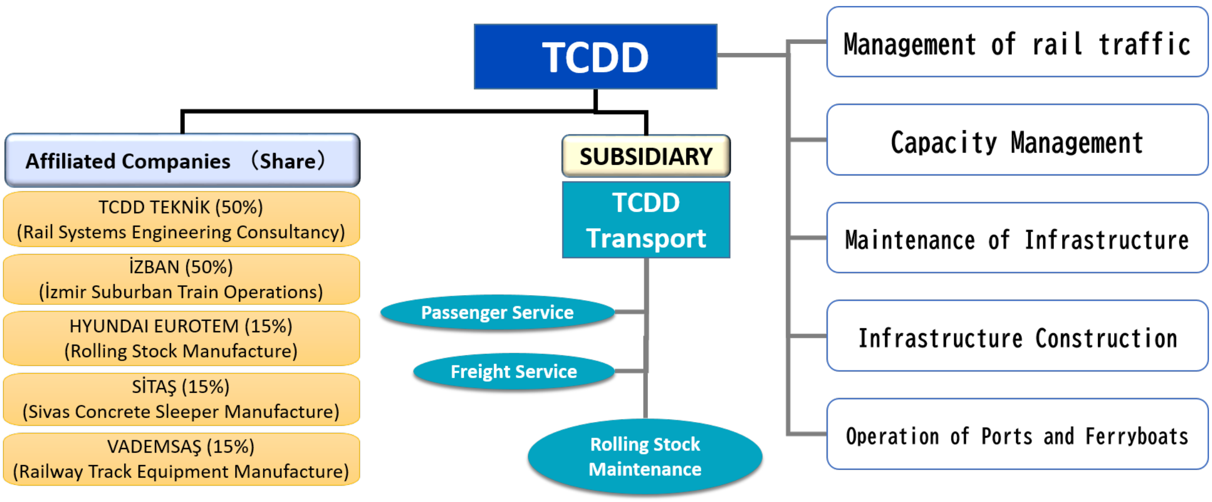
Source: TCDD

Figure 1-5 Relation Between MOT and TCDD

TCDD is responsible for the O&M (operation and maintenance) of high-speed rail and conventional rail infrastructure. TCDD has a stake in consulting companies and vehicle manufacturers.

TCDD Transport, a subsidiary of TCDD, handles the train operations and the vehicle maintenance for TCDD lines. The two companies were split up in 2017 with the aim of open access, which enables the entrance of private train operating companies in the future.

The roles of TCDD and TCDD Transport and the positioning of the investing companies are shown below (Figure 1-6).

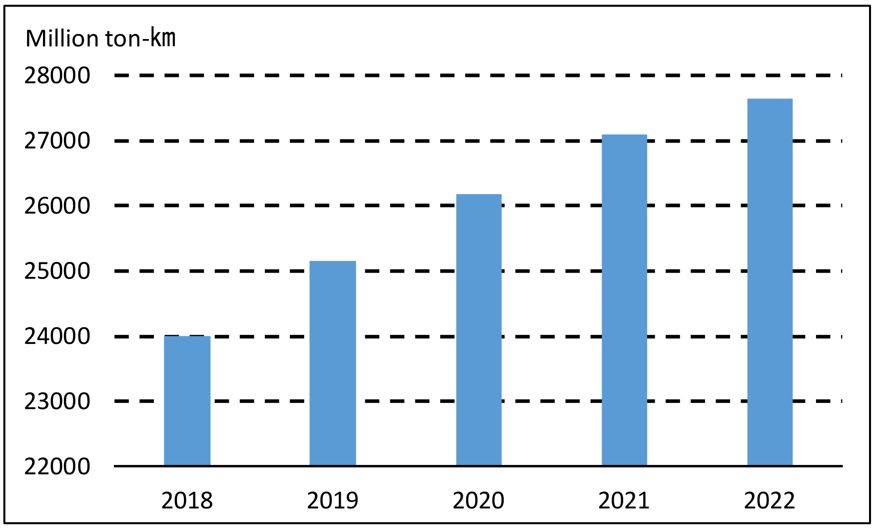


Source: TCDD

Figure 1-6 Relation Between TCDD/TCDD Transport/Affiliated Company

According to a statistical report issued by TCDD, the railway's modal share of Türkiye is 2.7% for passengers and 4.5% for freight as of 2020. In other words, the current situation is that the railway is not being selected as a primary mode for inter-city travel and transport in Türkiye.

However, freight traffic performance has continued to grow steadily from 2018 to 2022. The gross ton-kilometer of freight, including vehicle weight, has continued to grow steadily even in the COVID-19 period (Figure 1-7), indicating that TCDD is required to respond to strong freight demand.



Source: TCDD "ANNUAL STATISTICS 2018-2022"

Figure 1-7 Gross Ton-Kilometers Including Vehicle Weight per Year in TCDD (Freight Traffic)

(1) Conventional Line

An overview of the conventional lines owned by TCDD as infrastructure manager is given below (Table 1-2).

TCDD's conventional lines are mainly responsible for the urban transport as commuter lines in urban areas and primarily the freight transport between cities. This is because cars are the main mode of transportation between cities. Historically, the railway network was designed to connect the Middle East to Europe, not to connect cities to each other.

Table 1-2 Overview of the TCDD's Conventional Line

Item	Performance（2022）
Track operated	11668 ㎞
Ridership	303.32 million passengers
Passenger transport revenue	1,485,928,361TL (Including facilities usage revenue, high-speed rail revenue）
Freight operating performance（Freight net ton-km）	15,506,338,000ton-km
Freight transport revenue	1,255,829,294TL
Maximum operating speed	120 ㎞/h
Axel load	22.5 ton
Electrification rate	58.9%

Source: JST organized information based on the TCDD's data and MOT's data

TCDD's conventional lines operate multiple-unit electric trains and diesel or electric locomotive trains.

In the urban areas of Ankara and Istanbul, the trains are responsible for suburban transport. On the other hand, locomotive passenger trains operate in inter-city transport.

There are no disaster prevention systems or monitoring equipment on TCDD's conventional lines. Cameras have been installed to enable remote monitoring of the situation.

These Cameras are being installed near the tracks to transmit the status of the tracks and ancillary equipment to two technical centers in Ankara and Sivas. In the Centralized Traffic Control (CTC) section, where the CTC center controls the operation of each section, the camera images are transmitted to the CTC center via fiber-optical connections.

These cameras are effectively used to check the status of the tracks; however, visibility is extremely low at night, and there are no clear regulations or internal rules on utilizing the camera images for train operation control. For this reason, those cameras are not always operated effectively.

(2) High-Speed Rail (YHT)

An overview of the high-speed rail network owned by TCDD as infrastructure manager is given below (Table 1-3). Türkiye's high-speed rail network opened in 2009 between Eskeşehir and Ankara. Since then, Istanbul-Ankara, Konya (Karaman)-Ankara, and Sivas-Ankara have opened.

The maximum speed is 250 km/h on some sections. However, many other sections are being used with conventional trains where the maximum speed is reduced to around 200 km/h or 160 km/h.

Table 1-3 Overview of the TCDD’s High-Speed Rail Line

Item	Performance（2022）
Track operated	1,460 ㎞
Ridership	9.36million passenger
Maximum operating speed	250km/h
Signaling system	ETCS Level2

Source: JST organized information based on the TCDD’s data and MOT’s data

Similar to Japan’s Shinkansen, the high-speed rail uses power-distributed trains and its design follows the EN (European Norm) standard.

For this reason, the rolling stock initially adopted was based on Spanish high-speed trains. The latest rolling stock is based on Siemens' Velaro high-speed trains.

Source: JST

Figure 1-8 Rolling Stock for Velaro High-Speed Rail（TCDD HT80000）

On TCDD's high-speed rail lines, cameras are being installed just as on conventional lines. Some

structures are equipped with monitoring devices intended for maintenance. These monitoring devices transmit information to the technical centers in Ankara and Sivas.
TCDD reports that these devices were installed during the construction phase. However, the use and data utilization were not clearly defined within the organization.
AYGM assesses risks and decides on the installation of monitoring devices based on technical documents, which indicate the use of seismic sensors, wind gauges, and cameras. No additional devices have been installed beyond these.
In recent years, there have been many cases of flooding of high-speed rail tracks, which have affected the train operations. In such cases, it was confirmed that there were cases where anomalies were detected before the train approached using camera images.

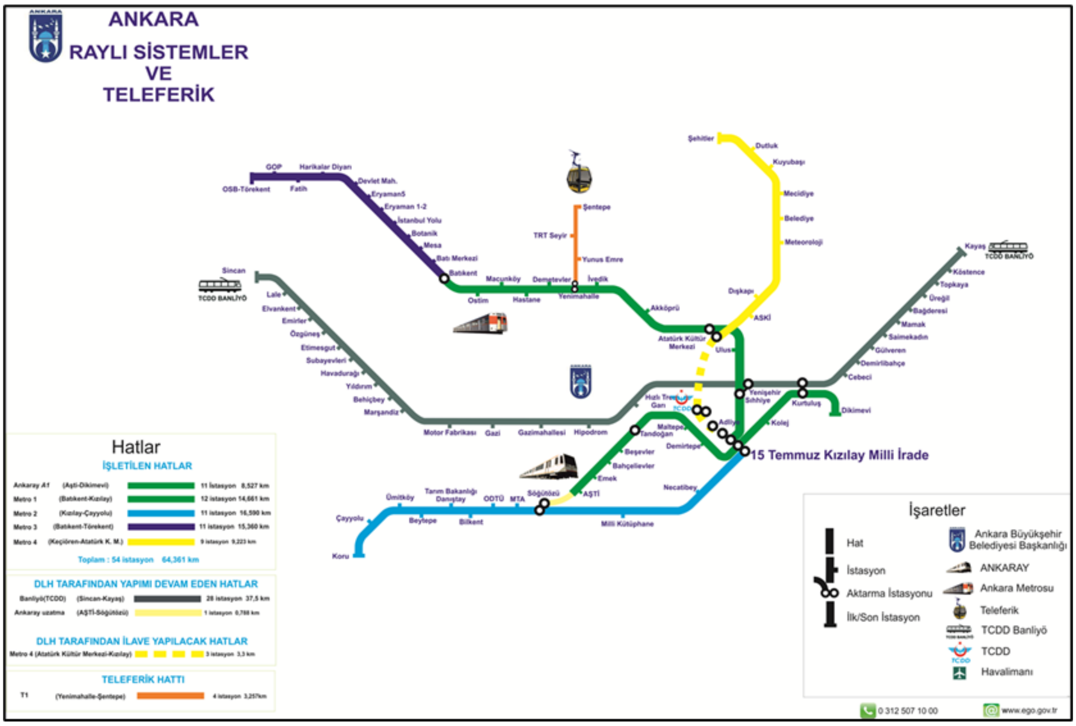
1.5 Overview of the Urban Railway System in Türkiye

As of April 2024, there are five cities in Türkiye operate an underground metro railway system: : Istanbul, Ankara, Brusa, İzmir and Adana. Among these, Istanbul, Ankara and İzmir have suburban commuter lines. The following is an overview of the Ankara and Istanbul metro lines, which are both large scale in coverage area and number of passengers and commuters.

1) Ankara Electricity, Gas and Bus Operations Organization (EGO)

The Ankara Electricity, Gas, and Bus Operations Organization (EGO) started supplying Ankara City with gas and electricity in 1942 as part of the Ankara Municipality, and started operating bus services in 1950 and metro services in 1996. By 2007, EGO ceased supplying electricity and gas services and now only EGO operates buses, metro and cable cars in the city.
As for the metro, the five lines have a total coverage of 67.93 km with57 stations in operation. The M1, M2 and M3 lines between Koru and OSB are operated as one via the M1 Line. Thus, EGO effectively operates three lines: Ankaray, M1, and M4. The depot for the Ankaray Line is located near the terminus at ASTI Station, while the M1 to M4 lines share common depots near Macunkoy Station and near the terminus at Koru Station, each with its own Operation Control Centre (OCC). According to the EGO's 2023 Annual Report, the number of passengers in 2023 reached 159 million (436,000 passengers per day). All lines have a 1435 mm gauge, third-rail 750 V system.

- Ankaray line (opened 1996, 8.5 km, ASTI-Dikimevi, 11 stations, light rail standard with 14.5 m car body length)
- Line M1 (opened 1997, 14.66 km, Kizilay-Batikent, 12 stations, 18 m car body length)
- Line M2 (opened 2014, 16.59 km, Kizlay-Koru, 11 stations, operates on a portion of M1)
- Line M3 (opened 2014, 15.36 km, Batikent-OSB, 11 stations, operates on a portion of M1)
- Line M4 (opened 2017, extended in 2023, 12.52 km, Kizilay-Gazino, 12 stations)



Source：EGO

Figure 1-9 EGO (Ankara Metro) Network

2) Metro İstanbul

Metro Istanbul, as part of the Istanbul Municipal Transportation Authority, operates under the Istanbul Metropolitan Municipality. It owns and operates a wide ranges of public transport services, including ten metro lines (M1 to M9, and M11), four tram lines (T1 to T4), cable cars (funicular), and ferries. Currently, three new MRT lines (lines M10, M12, and M14)are under construction, seven lines (M1, M3, M4, M5, M7, M9, and M11) are being under extended and one line (M13) is planned, the system comprises an operating length of 241.35 km, 234 stations and served 831 million passengers (2.28 million per day) in 2022 (data provided by Metro Istanbul).

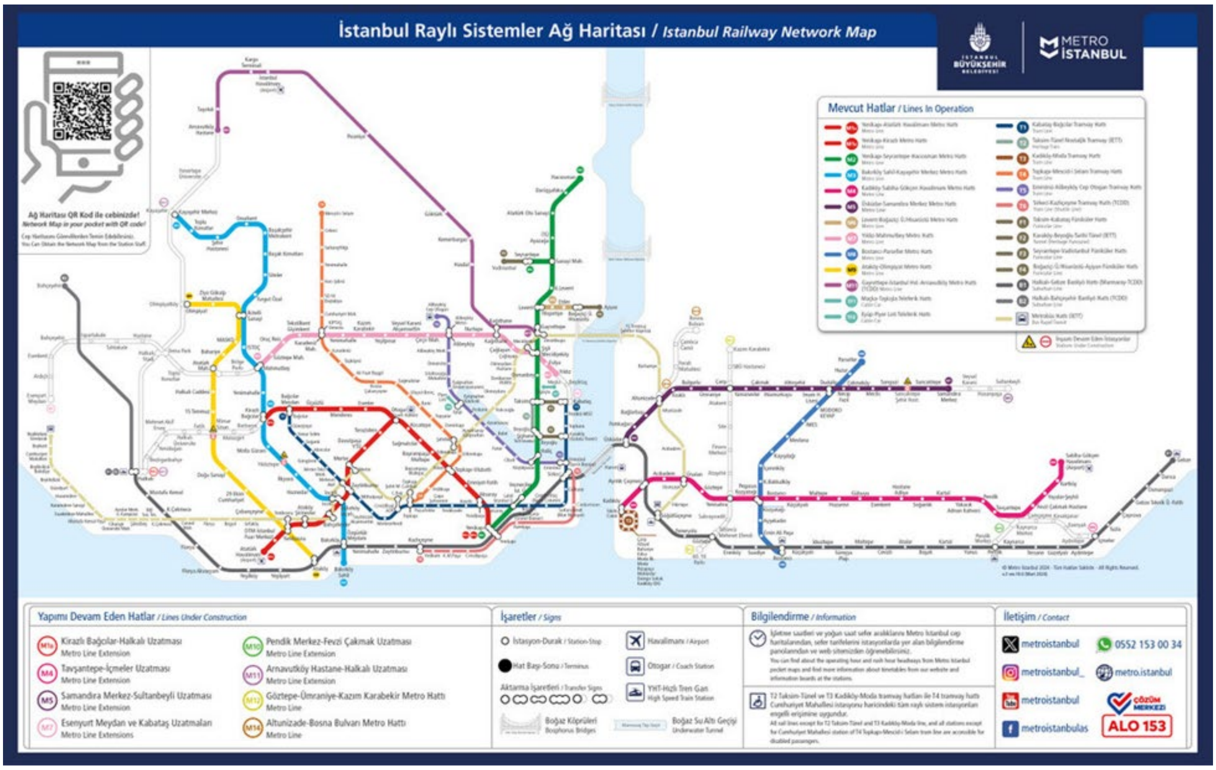
The city of Istanbul also has an undersea tunnel, the Marmaray Line, which was opened in 2013 and connects the European and Asian sides of the city. The Marmaray Line operates through service with TCDD-operated M11 Line, which already opened in 2023, and connects Istanbul Airport with the city center. This enables a direct link between the Marmaray and M13 Line. TCDD Transport (tur: TCDD Taşımacılık) operates both the Marmaray and M11 lines, while Metro Istanbul operates the remaining metro lines.

All metro lines use the standard 1435 mm track gauge, but the system has a mixture of light metro and full metro service, powered by either third rail or overhead contact line. The M11 line, which runs long distances to Istanbul Airport, and has a maximum speed of 120 km/h. The main metro lines are listed below.

- M1 Line (opened in 1989, 26.8 km, 23 stations, overhead contact line 750 V, light rail standard, maximum speed 70 km/h)
- M2 Line (opened in 2000, 23.49 km, 16 stations, third rail DC 750 V system, maximum speed 80

km/h)

- M4 Line (opened in 2012, 16.59 km, 11 stations, 1500 V DC overhead contact line, maximum speed 80 km/h)
- M11 Line (opened in 2023, 51.5 km, 16 stations, 1500 V DC overhead contact line, maximum speed 120 km/h)
- Marmaray Line (opened in 2013, total length 76.3 km, tunnel length 13.6 km, 3 new stations, 37 existing stations, 1435 mm gauge, 25kV AC overhead contact line, maximum speed 100 km/h).



Source: Metro Istanbul

Figure 1-10 Istanbul Metro Network (As of 2024)

1.6 Review of Assistance Provided by Donors Other Than Japan

With the cooperation of international organizations such as the World Bank (WB) and the United Nations Development Program (UNDP), numerous reports have been published regarding the actual damage caused by the earthquake and the future support measures.

In reviewing the transport sector in these reports, reports mentioned that support for the sector is mainly being considered in the context of supply chain restoration. It was difficult to identify any recommendations on the need for support for restoration specifically for railways.

The WB then announced the implementation of the Türkiye Earthquake Recovery and Reconstruction Project[1] in June 2023.

[1] https://www.worldbank.org/en/news/press-release/2023/06/27/world-bank-approves-1-billion-for-turkiye-to-help-restore-rural-homes-and-essential-public-services-to-people-in-earthqu (Accessed May 17, 2024)

The WB funds this and will support reconstructing the areas affected by the Türkiye-Syria earthquake. Among the initiatives, three components are of particular relevance to reconstruction: Component 1 is the restoration of water supply, water, and other services, and the restoration of firefighting facilities and other disaster management agencies; Component 2 is the restoration of public health services; and Component 3 is livelihood assistance for the affected population.
The WB project has a total funding of USD 1 billion.

Other assistance was provided by EBRD (European Bank for Reconstruction and Development), IsDB (Islamic Development Bank), and AIIB (Asian Infrastructure Investment Bank). However, assistances are mostly on health infrastructure, housing reconstruction, and economic activities, including assistance to SMEs (Small and Medium-sized Enterprises). No restoration assistance for large-scale railways or other infrastructure was identified.
The table below summarizes the recovery assistance provided by each donor (Table 1-4).
It should be noted that although the plan initially announced by EBRD in March 2023, immediately after the main earthquake, included support for the restoration of railways, EBRD data did not confirm any subsequent contributions. According to TCDD, foreign funds have not been utilized to restore the railways.

Table 1-4 Assistance Provided by International Donors

Donor	Description	Amount(Currency)
WB	Support for restoration of water, sewerage and sanitation infrastructure Support for restoration of firefighting and other emergency response-related facilities Support for reconstruction of housing	1000 million (USD）
EBRD[2]	Support for economic activities in the affected areas (with support from banks in Türkiye) Support to SMEs in the affected areas Support to enterprises engaged in rehabilitation activities	6 million（EURO）
IsDB[3]	Emergency financial assistance Support for agricultural recovery in the affected areas and support for food-related enterprises Support for economic recovery in the affected areas	4.2 million（USD）
AIIB[4]	Emergency assistance to affected areas Support for the construction of green infrastructure (as part of	3 million（USD）

2 https://www.ebrd.com/work-with-us/projects/psd/54408.html (Accessed June 14, 2024)
3 https://www.isdb.org/hub/turkey/news/isdb-group-and-turkiyes-treasury-and-finance-ministry-sign-us120-million-financing-agreement (Accessed June 14, 2024)
4 https://www.aiib.org/en/projects/details/2023/approved/Turkiye-Turk-Eximbank-Earthquake-Response-Project.html (Accessed June 14, 2024)

Donor	Description	Amount(Currency)
	the recovery from this disaster)	

Note: The description and amount were combined if multiple projects/programs are implemented
Source: JST organized

The railway support from the respective donors could not be confirmed at present.
On the other hand, it was confirmed that apart from the restoration of the Türkiye-Syria earthquake, the WB and AIIB are supporting the development of conventional railways in Türkiye.
The project aims to secure a freight route through Türkiye's Georgian border towards Europe through co-financing from WB and AIIB. An overview of the project is given in the table below (Table 1-5).

Table 1-5 Finance Support for Railway Project From WB and AIIB

Item	Description
Name	Eastern Türkiye Middle Corridor Railway Development Project (Renamed from International Rail Logistics and Network Resilience Project)
Section	Divriği – Erzincan – Erzurum – Kars – Georgia Border Railway Corridor
Distance	660 ㎞
Planned work	Construction of new line for 143 ㎞ Installation of signaling, telecommunication, and electrification systems Construction/rehabilitation of sidings, bridges, terminals, stations, and other facilities.
Project cost	1,344.6 million USD (Includes 183.9 million USD in funds from the Turkish Government)
Donor	WB (funding by International Bank for Reconstruction and Development), AIIB and IsDB（WB: 660 million USD, AIIB: 250 million USD, IsDB: 250.7 million USD ）

Source: WB[5], AIIB[6] and IsDB[7]

According to WB officials, the project aims to strengthen the inland transport routes from Central Asia to Europe, which WB considers an issue. It highlights WB's view that Turkish rail infrastructure is essential as a logistics route connecting Asia and Europe.
In addition to the structural measures to strengthen the infrastructure described, the above-mentioned study also included a study to introduce an early warning system using various monitoring devices to be installed on TCDD's high-speed rail lines and on the new extensions. However, according to WB, this component has been temporarily canceled due to insufficient research in terms of ROI and inadequate research on the concept.

5 https://projects.worldbank.org/en/projects-operations/project-detail/P179128 (Accessed March 14, 2025)
6 https://www.aiib.org/en/projects/details/2024/_download/Turkiye/AIIB-PSI-P000646-Eastern-Turkiye-Middle-Corridor-Railway-Development-Project.pdf (Accessed March 14, 2025)
7 https://www.isdb.org/hub/turkey/news/islamic-development-bank-group-and-turkiyes-treasury-and-finance-ministry-sign-euro-24640-million-financing-agreement-for-turkiyes-middle-corridor-railway-project (Accessed March 14, 2025)

According to WB officials, the monitoring equipment is not only intended for disaster prevention but is also expected to be used for maintenance decisions and to supervise operators who will participate in the future through open access.

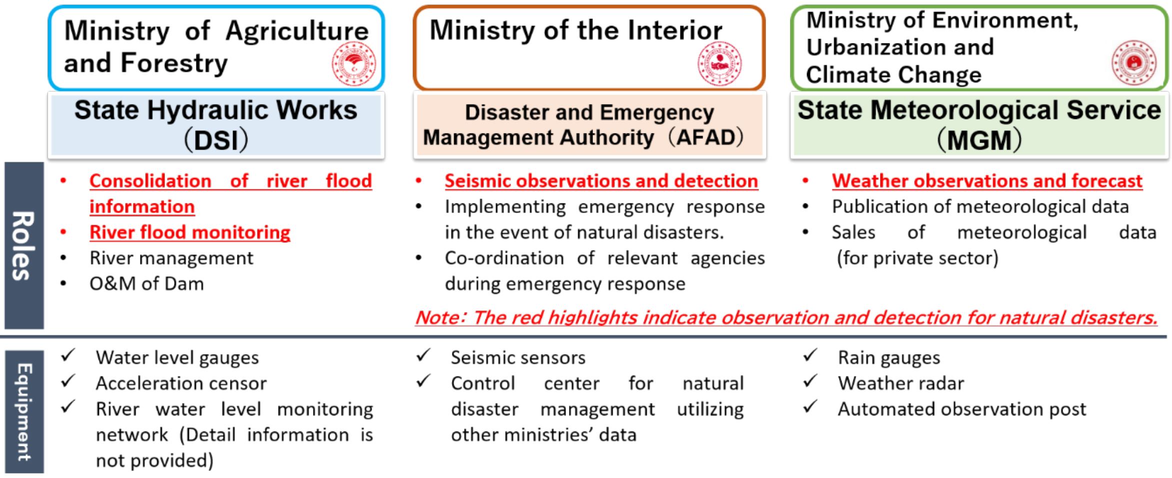
1.7 Current Status of Natural Disaster Observation Networks in Türkiye

In Türkiye, natural disasters, particularly earthquakes and landslides, occur frequently. For this reason, the respective ministry monitors relevant natural disasters, and takes action when necessary. The natural disaster monitoring networks and the ministries with jurisdiction over them are summarized below (Figure 1-11).

It should be noted that no ministry in Türkiye, like the Ministry of Land, Infrastructure and Transport (MLIT) in Japan, was identified to centrally monitor and manage infrastructure damage in the event of a disaster.

As described below, it was confirmed that AFAD installed and maintained seismographs under the Ministry of Interior. DSI (Devlet Su İşleri Genel Müdürlüğü: State Hydric Works) installed the river level gauges under the Ministry of Agriculture and Forestry. MGM (Meteoroloji Genel Müdürlüğü: Turkish State Meteorological Service) installed weather radars under the Ministry of Environment and Urban Climate Change.

These monitoring systems and observation data are not used for decision-making on railway operations.



Source: JST

Figure 1-11 Natural Disaster Monitoring System and Relevant Ministries in Türkiye

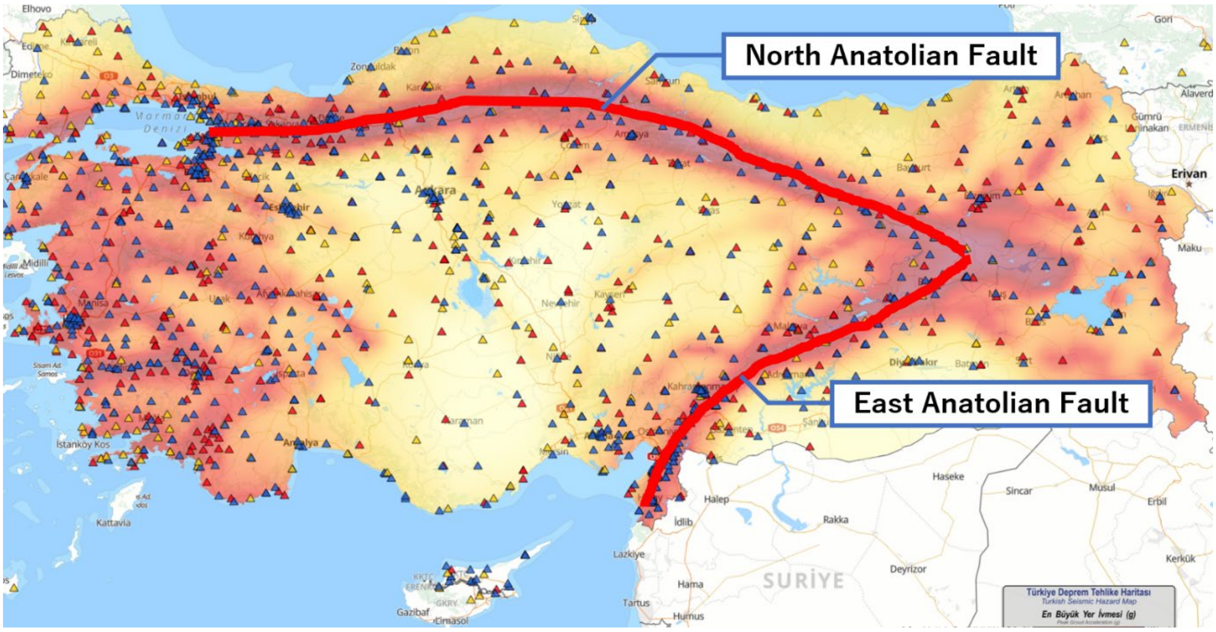
(1) Earthquake Monitoring Network

Seismic networks utilizing accelerometers have been established in Türkiye; according to AFAD, 317 velocity seismometers and 826 acceleration seismometers formed the observation network as of January 2024. In 2021, 23,763 earthquakes were measured.

Figure 1-12 below shows the seismograph network published by AFAD in Türkiye. The triangular icons indicate the location and type of seismometer (accelerometer, velocimetry). The darker-colored areas are those considered high risk in the seismic hazard map.

There are two major faults in Türkiye that are considered particularly dangerous, and a network of seismometers has been installed along the North Anatolian Fault and the East Anatolian Fault, as well as a large number of seismometers in the densely populated Istanbul urban area.

AFAD also carries out risk analyses of landslide and slope hazards in Türkiye and provides information on hazardous areas through an information analysis system called AFAD ARAS. The results are publicized on the AFAD's Disaster Management Support System (AYDES).



Source: AFAD website[8]

Figure 1-12 AFAD's Seismic Network

(2) River Level Gauges Network

According to previous JICA reports[9], DSI is an organization that carries out tasks related to water resources management, such as river management, flood control, and dam construction.

It is presumed that DSI is carrying out river level monitoring, as mentioned above.

In addition, past surveys and a desktop survey revealed that DSI is conducting flood risk analysis and other activities in rivers in Türkiye.

Therefore, JST held an interview with DSI on June 25 to collect information on the monitoring observation network including water level observations under the control of DSI, as well as DSI's role in disaster management. A summary of the results of the survey is provided below.

<u>Regarding the monitoring and observation network managed by DIS</u>

a.) It monitors water levels, snowfall (about 1300 stations in total), etc., but does not directly monitor railway facilities. The measurement information is available online. The measurement equipment itself

[8] https://deprem.afad.gov.tr/stations (Accessed April 22, 2024)

[9] Data Collection Survey for Disaster Resilient Urban Planning in Turkey (2014)

is also online.

b.) Information is shared from DSI to the Water Management Agency and the Ministry of Agriculture upon request. However, DSI only measures areas related to dams, etc. Therefore, DSI does not measure water levels in areas close to TCDD lines, etc., and does not necessarily have a comprehensive observation network.

c.) Flood early warnings are for DSI internal use only and are not distributed externally.

d.) For monitoring of rivers, general measurement equipment is used, such as accelerometers, water level gauges, etc.

e.) DSI has cooperated in providing observation data on rivers at the request of TCDD. In addition, when railway operators deploy their own disaster prevention systems, they can use the information from DSI, but there has been no request from TCDD to do so so far.

f.) The disaster prevention network system that DSI has is also similar in structure and configuration to Japan's PreDAS.

Role of DSI in Disaster Management

a.) DSI's tasks are flood management, (some of which are also transferred to the local municipality), pre-disaster prevention, recovery response, and post-disaster prevention. In urban areas, the municipality is responsible for response.

b.) The activities of DSI are divided into Structure and Non-structure. Structure is responsible for creating flood management facilities. Non-structure manages the monitoring and warning (Early-Warning system). (MGM is in charge of weather forecasting, so it collects information on rivers).

c.) Centralized management of flood management and river monitoring information: Municipalities are responsible for some river management and urban flood control-related infrastructure construction and management, and while DSI is in charge of river floods. Dams, flood control, and river management are also major tasks. Therefore, DSI cannot take charge of all flood management and has limitations in data collection (it does not collect data on city floods), leaving some of the responsibility to the municipalities.

d.) After a flood event, DSI is responsible for post-response, assessment of the health and damage of infrastructure facilities, etc. Restoration of facilities managed by DSI is carried out by DSI. As DSI is responsible for conducting river-bed cleaning after a flood event, other railway facilities are to be conducted by each railway operator (on the infrastructure side).

e.) DSI has experience in rehabilitating railway facilities and structures, but there are no reports on this. DSI cannot touch anything that is not within its scope, but river-bed is within its jurisdiction.

f.) In the event of a disaster, information will be shared via the Crisis-Coordination Center (located in the area of occurrence), in which DSI and AFAD also participate. Information, personnel, and equipment are shared according to the capabilities of each relevant ministry. Thus, a post-disaster response system is in place. In addition, if an alarm is raised within DSI, it is shared internally, but not with AFAD. Basically, DSI alarms are not shared with external parties.

Other information on DSI

a.) Capital investment in measuring equipment and facilities against flooding is fully funded by the government budget.

b.) There have been no cases of support from relevant domestic ministries, although some equipment has been loaned to AFAD in recent years, but that is all.

c.) DSI is responsible for setting the criteria for river flood control, and if not followed, the entity that designed it will be held responsible. The Ministry of Environment, Urban Affairs and Climate Change is responsible for setting the criteria for seismic protection.

(3) Weather Radar Network

MGM carries out meteorological observations in Türkiye.
It is the largest provider of meteorological information in Türkiye and also collects meteorological data. MGM noted that there are some small private weather companies, but none of them provides railway weather services. MGM is a member of the observation network of the World Meteorological Organization (WMO) and publishes weather radar information.
The WMO website shows that MGM has a network of 17 C-band radars and four X-band radars. JST will interview MGM to collect information on their observation network (Figure 1-13).
A discussion was held with MGM on June 25 to gather information regarding the weather observation network owned by MGM and its role in disaster management. A summary of the results of the survey is provided below.

a.) The observation network consists of 2000 automatic observations (rainfall, temperature, wind speed and direction), 18 weather radars, 41 lightning strike detection and 9 radiosonde locations. The data is used for forecasting, and as a result, alerts are issued if necessary.

b.) MGM's operations include providing information to each stakeholder, and stakeholders include government agencies, citizens (local residents), and others. The information can be communicated simultaneously to the communication pool in which the stakeholders participate, and the information is also available on the MGM mobile application. Note that MGM can only issue regional forecasts and warnings, but there are examples of this information being used by road and aviation stakeholders.

c.) MGM is responsible for observation and forecasting, not disaster management. When it issues an alert, it does so whether or not it causes a disaster. The content of the alert is to provide information and warnings of possible disasters. Since the actual type of disaster caused by each weather condition depends on the situation and environment, MGM's responsibility is limited to issuing the alert. The criteria for issuing warnings are based on the criteria determined by MGM.

d.) Risk assessment, damage assessment and forecasting of disasters are not the responsibility of MGM.

e.) If TCDD wants to use weather information, it can access it on the web, but it is not a constant or explicit data sharing system, nor has it been provided to railway operators in the past.

f.) There are no examples of MGM providing weather consultation or other services to specific industry sectors; MGM's business is solely to provide general weather information, not to provide services for specific sectors.

g.) There is a system of collaboration with other ministries, providing real-time information to some ministries such as AFAD. The assumption is that the information can be provided upon request.

h.) Automatic observation data can be sold to outside firms.

Note: Green icon shows C-band radar and red icon shows x-band radar
Source: WMO website[10]

Figure 1-13 Existing Weather Radar Network in Türkiye

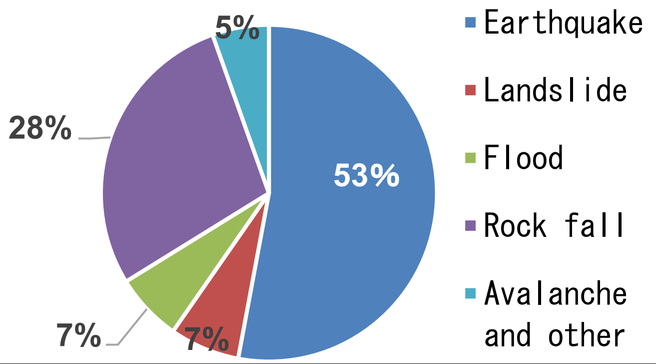
[10] https://wrd.mgm.gov.tr/Home/Wrd (Accessed April 22, 2024)

Chapter 2 Identification of Disaster Risks Close to Railways

2.1 Natural Disaster Risks in Türkiye

For identifying disaster risks to the railway in Türkiye, according to the reports by the Turkish government in 2008 summarizing the occurrence of natural disasters in Türkiye over the past 100 years (Figure 2-1), more than 90% of buildings which collapsed due to natural disasters were caused by earthquakes, landslides, floods, and falling rocks.

Causes	Case number	Ratio (%)
Earthquake	495,000	53
Landslide	63,000	7
Flood	61,000	7
Rock fall	265,000	28
Avalanche and other	51,000	5
Total	935,000	100

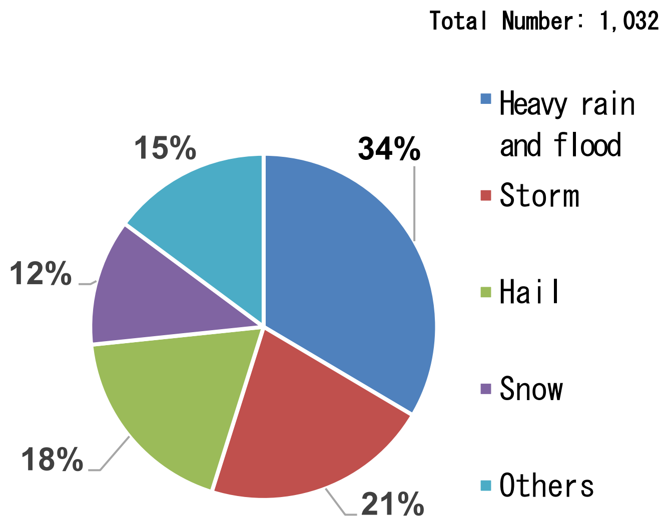


Source: JST prepared based on data in TURKISH REPUBLIC COUNTRY REPORT ON DISASTER MANAGEMENT (2008)

Figure 2-1 Damage to Buildings Due to Natural Disasters in the Past 100 Years

The number of meteorological disasters in Türkiye in 2022 and 2023 is 1,032 and 1,475, respectively, and the breakdown is shown in Figure 2-2 and Figure 2-3. Among meteorological disasters, changes in the number of heavy rain and flood events (1940-2022) are shown in Figure 2-4. Heavy rain and flood accounts for the highest percentage of the total number of incidents, and the number of heavy rain and flood incidents has increased in recent years.

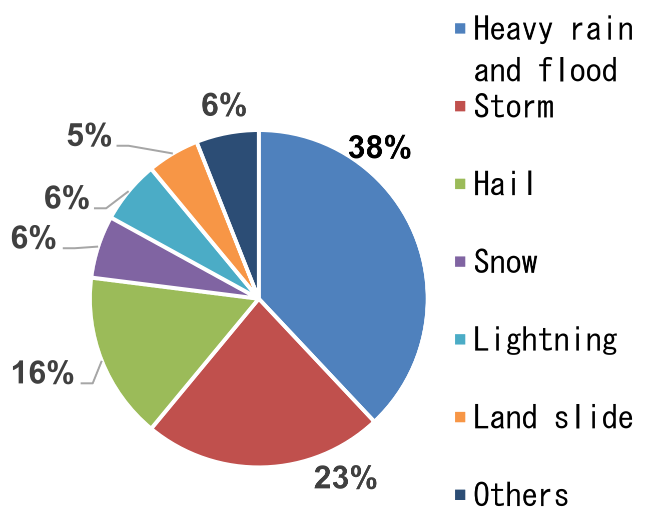
Disaster	Case Number	Ratio, %
Heavy rain and flood	346	34
Storm	220	21
Hail	191	18
Snow	122	12
Others	153	15
Total	1,032	100



Source: JST prepared based on data in MGM "2022 Meteorological Disasters Assessment"

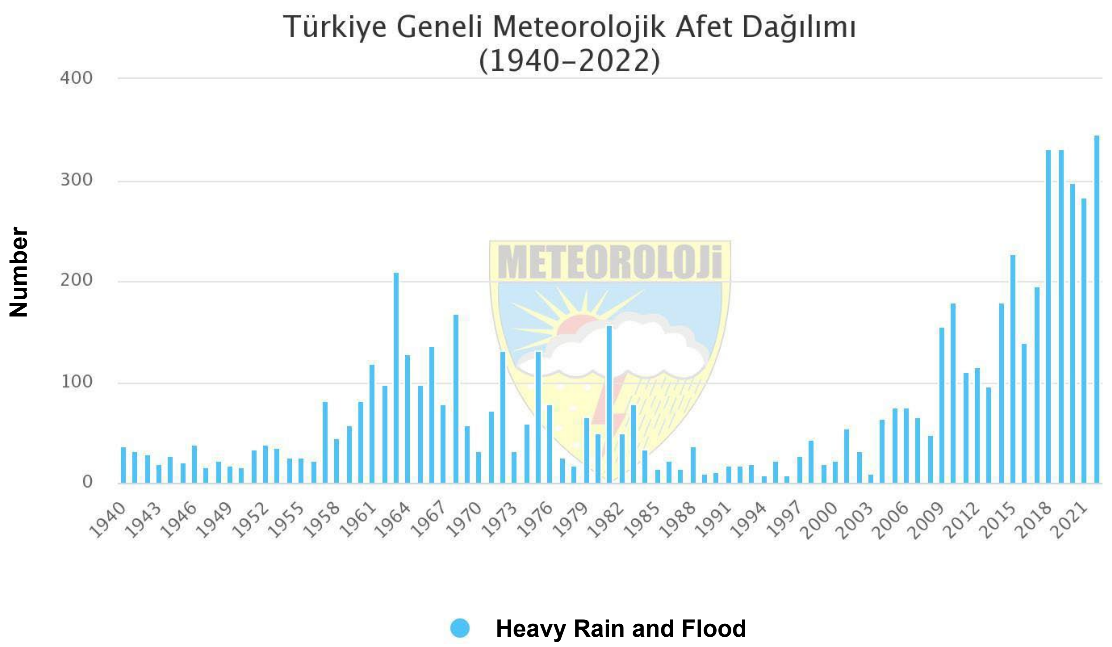
Figure 2-2 Breakdown of the Number of Weather Disasters in 2022

Disaster	Case Number	Ratio, %
Heavy rain and flood	561	38
Storm	339	23
Hail	236	16
Snow	89	6
Lightning	89	6
Land slide	74	5
Others	87	6
Total	1475	100



Source: JST prepared based on data in MGM "YEAR 2023 CLIMATE ASSESSMENT"
(The case number of each disaster type has been calculated by JST based on the total number and the ratio.)

Figure 2-3 Breakdown of the Number of Weather Disasters in 2023



Source: MGM "2022 Meteorological Disasters Assessment"

Figure 2-4 Trends in the Number of Heavy Rain and Flood Events in Türkiye (1940-2022)

During the visit in February 2024, we held a session and exchanged opinions with TCDD about this study, and organized a specific list of disaster risks based on TCDD's understanding of the issues. TCDD described how several railway lines were cut off due to slope sliding and rock falls in the Türkiye-Syria Earthquake (Figure 2-5). It was also mentioned that flooding caused by heavy rains had occurred 19 times on high-speed railways between 2020 and 2023. As a countermeasure for flooding, drainage pipelines under the railway tracks were built by temporarily removing the tracks, excavating embankments and installing crossing pipes.

Source: JST

Figure 2-5 Presentations from TCDD in the Session Held in February 2024

Based on the above, it was confirmed that disasters with the highest priority for establishing the railway disaster prevention system are "slope slides" and "rock fall" due to earthquakes and "flooding" due to rainfall.

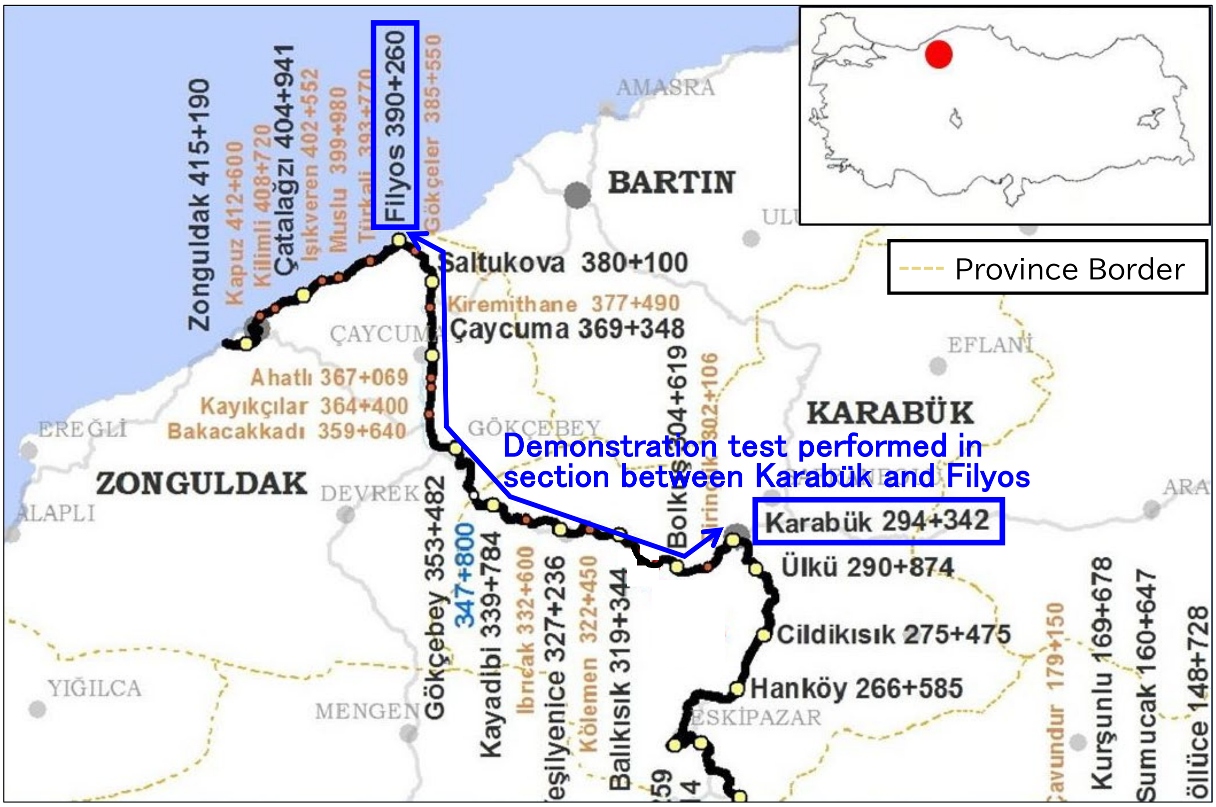
2.2 Disaster Risk Screening for the Demonstration Test

2.2.1 Disaster Risk Screening for Karabük-Filyos Section on TCDD conventional line

In the field survey in February 2024, to identify disaster risks on the TCDD line between Karabük and Filyos (Figure 2-6), JST held an interview with the TCDD Karabük Station manager and operation manager and asked the managers to explain the outline of the TCDD line. The results of the interviews are shown below.

- Karabük is important city where TCDD transports iron ore and coal unloaded at the port on the Black Sea coast to the Karabük steelworks and then transports the manufactured iron products to various parts of Türkiye. The railway has been in service for 130 years in Karabük.

- The number of heavy rain disasters occurring in 2023 is expected to be the highest in the past 30 years. After heavy rain, the amount of water seeping inside tunnels worsens, which is believed to be caused by rising groundwater levels.
- There are also many rockfall disasters with 6 to 7 incidents occurring per year. In January 2024, a freight train derailed due a rock fall.



Source: JST prepared based on data in UEIM Report

Figure 2-6 Provincial Area of the Section Between Karabük and Filyos

Source: JST

Figure 2-7 Interview at Karabük Station

After the interview, JST rode in a TCDD maintenance vehicle and made a tour of the approximately 90 km section between Karabük and Filyos to grasp the site situation.

During the tour, it was confirmed that TCDD had implemented tangible countermeasures against falling rocks, such as rock fall protection retaining walls (Figure 2-8), which were initially constructed nearly 100 years ago, rock fall protection nets (Figure 2-9), and corrugated tunnels. Also, because the limited budget of TCDD limits its ability to take structural measures, it confirmed the possibility of taking non-structural measures, such as using sensors and railway disaster prevention system.

Figure 2-8 Rock Fall Protection Wall Constructed 100 Years Ago

Figure 2-9 Rock Fall Protection Wire Mesh Constructed by TCDD

Source: JST

The first 50 km between Karabük and Filyos is a mountainous section with many cut slopes and river crossing bridges (Figure 2-10), similar to mountainous railway routes in Japan (e.g. Joetsu Line, Dosan Line). According to data from the General Directorate of Mineral Research and Exploration (MTA) (Figure 2-11), there are records of landslides along the route.

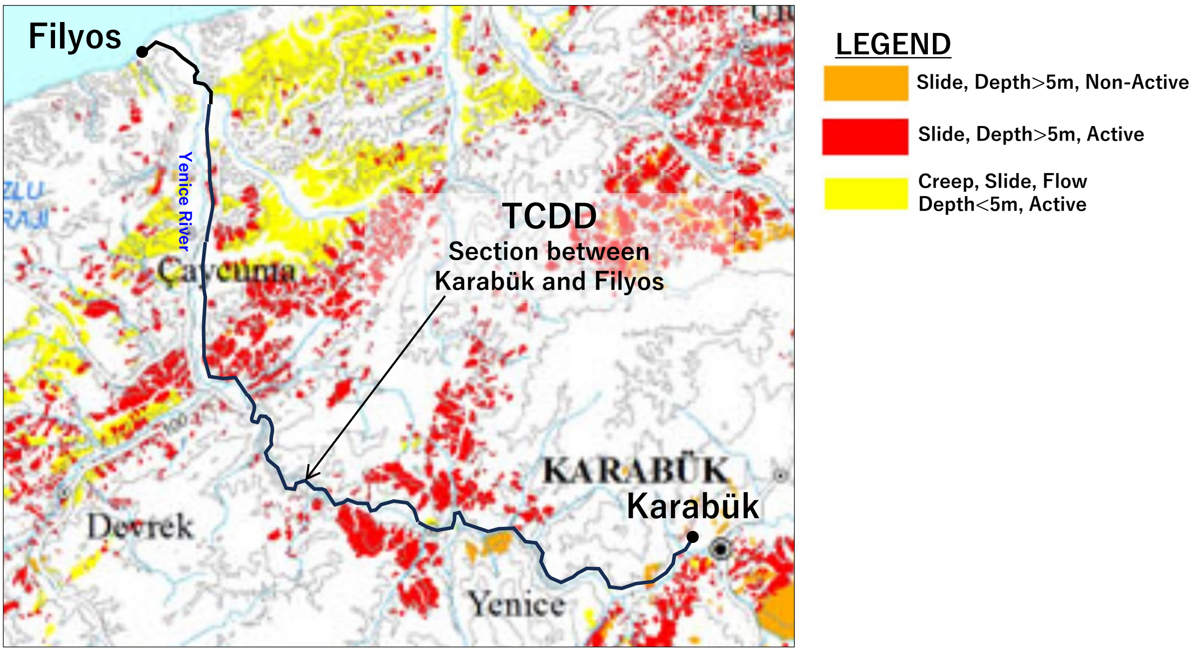
Comparing with the geological classification by geological map (Figure 2-12), landslides have been recorded over a wide range in areas with clastic and carbonate rock (lower to middle Eocene), while landslides have been recorded in limited areas in clastic and carbonate rock (lower Cretaceous) areas. The Cretaceous period is earlier than the Eocene period, and even with the same clastic and carbonate rocks, the geological regions of the Cretaceous period form hard and steep topography, while the regions of the Eocene period form gentle topography.

Disasters caused by large landslides and falling rocks have occurred in the mountainous areas of the

Joetsu Line and Dosan Line in the past. In July 1972, near Shigeto Station on Dosan Line, heavy rain caused a landslide, and a train was swept away by the landslide. In March 1977, between Tsukuda and Iwamoto Stations on the Joetsu Line, a rock weighing approximately 30 tons fell from a mountain slope breaking through a concrete barrier and falling onto the tracks. An express train was struck by the rock and derailed (Figure 2-13). One person was killed, and 109 were injured by this accident. This accident served as an impetus for measures to prevent rockfall, leading to the strengthening of disaster prevention facilities for rock falls, the expansion of national disaster prevention subsidies, and the creation of handbooks for rock fall prevention.

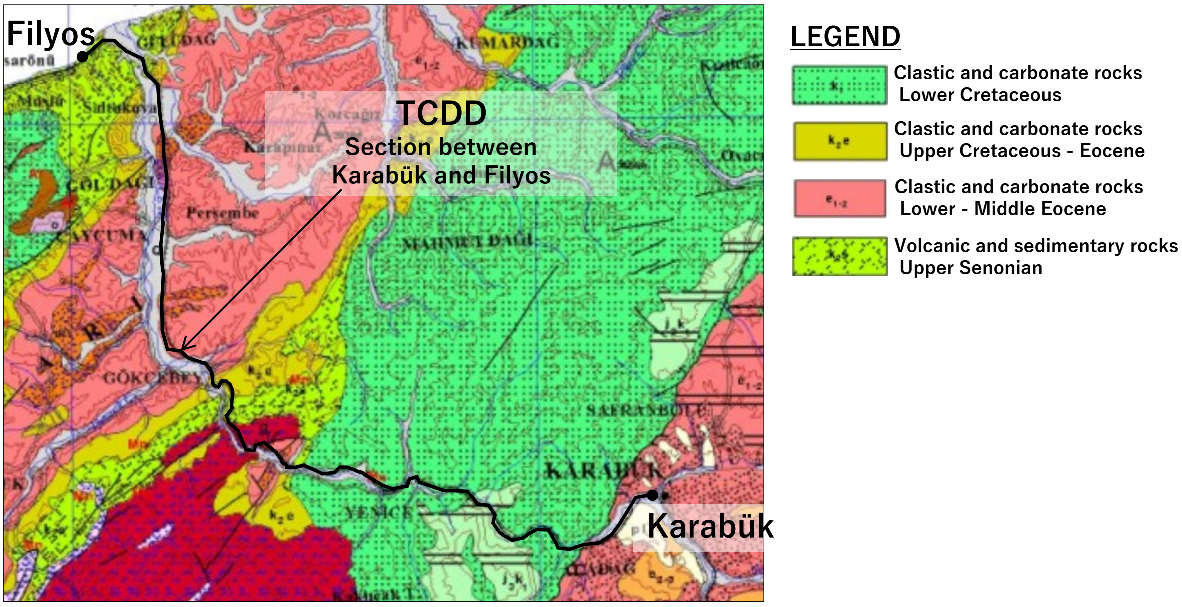
Source: JST

Figure 2-10 Cut Slope Sections and Mountain Routes Along Rivers



Source: JST prepared based on data in General Directorate of Mineral Research and Exploration (MTA) "1:1,500,000 Scale Landslide Inventory Map of Turkey", May 2011

Figure 2-11 Landslide Locations Based on Landslide Inventory Map



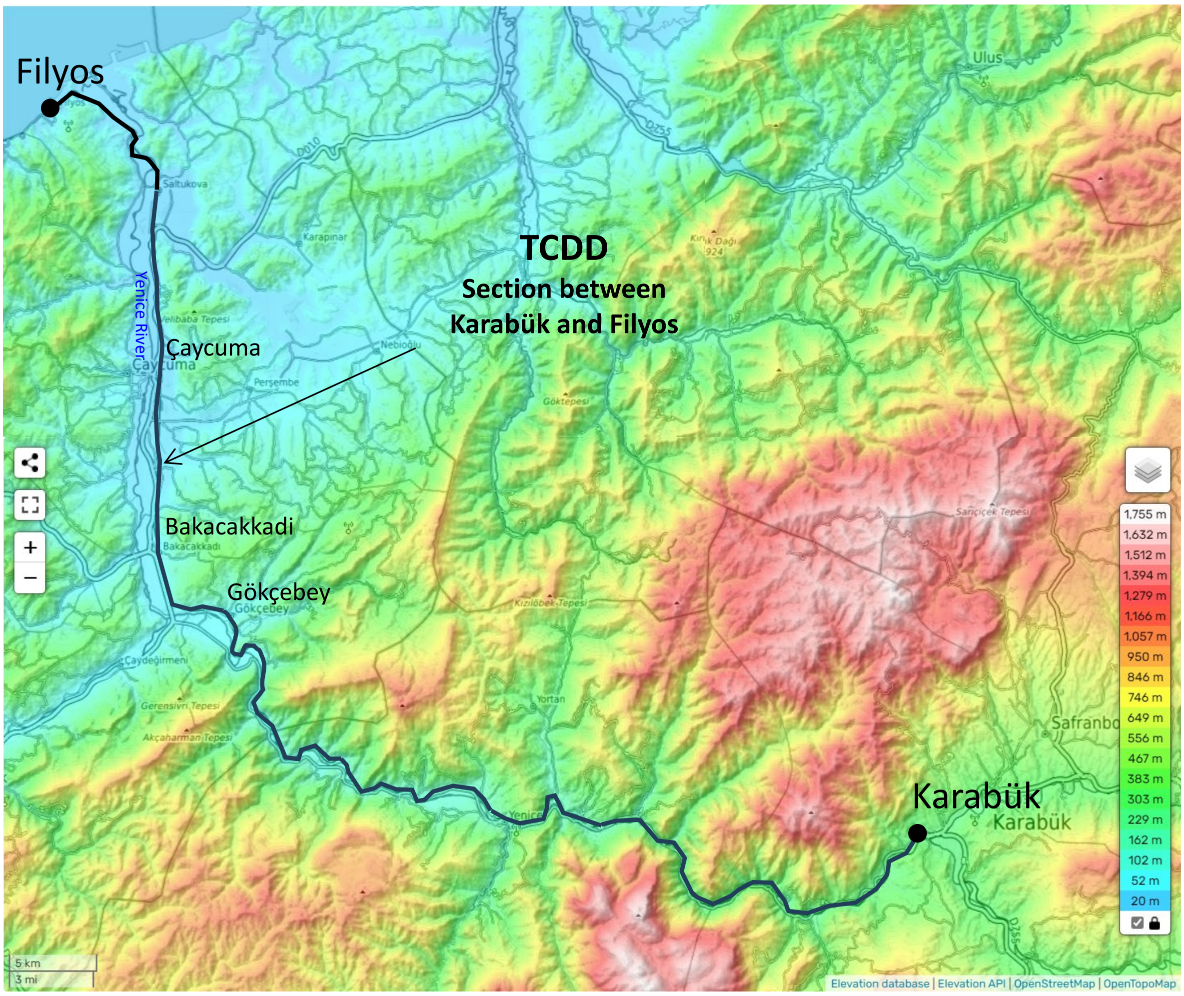
Source: JST prepared based on data in General Directorate of Mineral Research and Exploration (MTA) "1:500,000 Scale Geological Map of Turkey", 2002

Figure 2-12 Geological Classification by Geological Map

Source: JST

Figure 2-13 March 1977 Joetsu Line Derailment Accident Between Tsukuda and Iwamoto Stations

In the relatively flat area along the Yenice River after passing through the mountainous area, the elevations in the east and west sides of the river are higher than the area near the river (Figure 2-14). Water is collected towards the Yenice River which the TCDD route runs along. For this reason, not only the mountainous sections but also the flat sections along the Yenice River are at risk of flooding due to heavy rain.

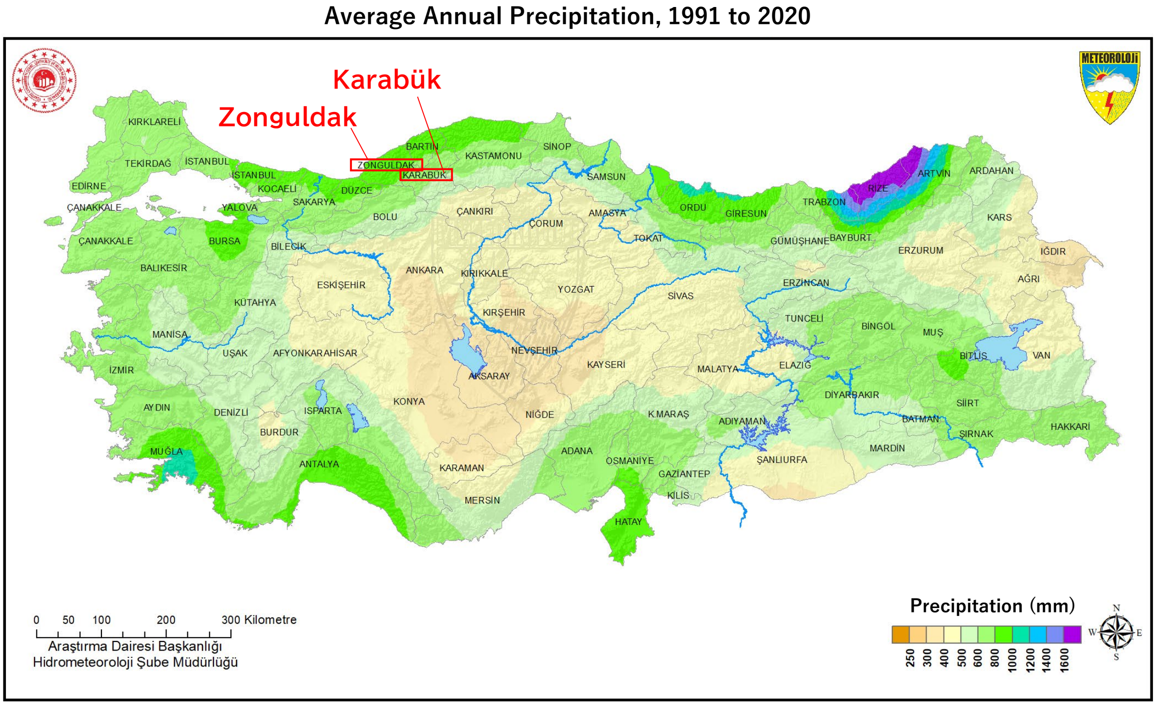


Source: JST prepared based on data in "topographic-maps.com"

Figure 2-14 Elevation Along the Section Between Karabük and Filyos

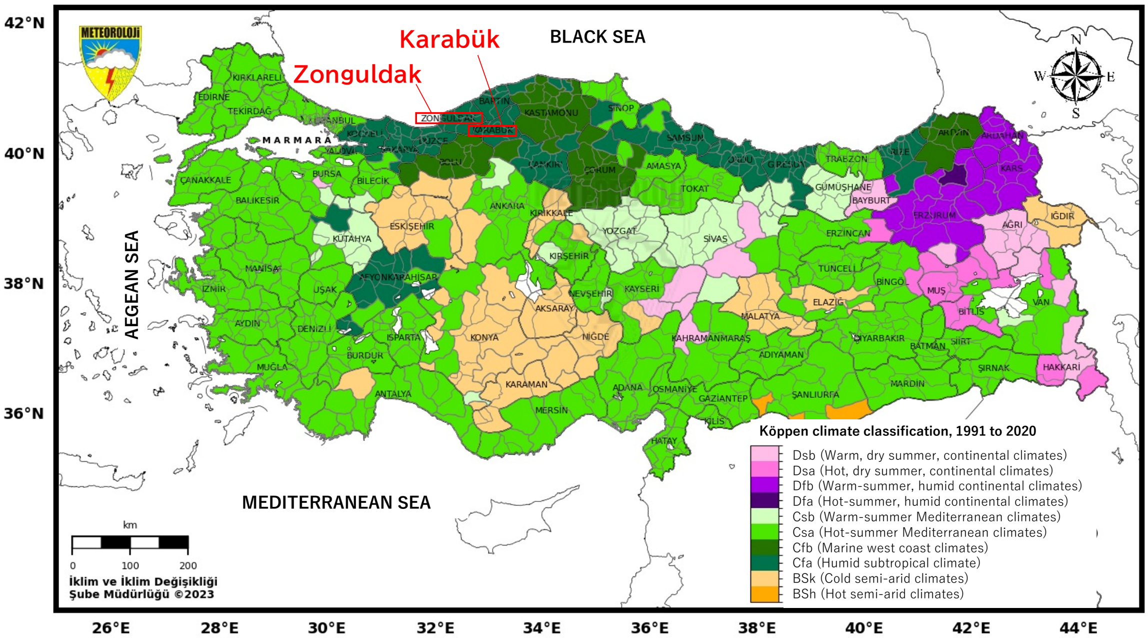
Figure 2-15 shows the annual rainfall in each region of Türkiye (average from 1991 to 2020). The Köppen climate classification is shown in Figure 2-16. Karabük Province and Zonguldak Province, which include the TCDD section, are areas with relatively high rainfall in Türkiye due to their warm and humid climate near the Black Sea.

Figure 2-17 and Figure 2-18 show the monthly average precipitation and average number of rainy days in Karabük and Zonguldak provinces. Although summer precipitation is relatively low, it is a region with precipitation throughout the year. Zonguldak Province, which faces the Black Sea, receives more annual precipitation than Karabük province, and is close to the annual precipitation of Tokyo in Japan (1396.5 mm in 2023).



Source: JST prepared based on data on MGM Website[11]

Figure 2-15 Annual Rainfall in Türkiye (Average From 1991 to 2020)

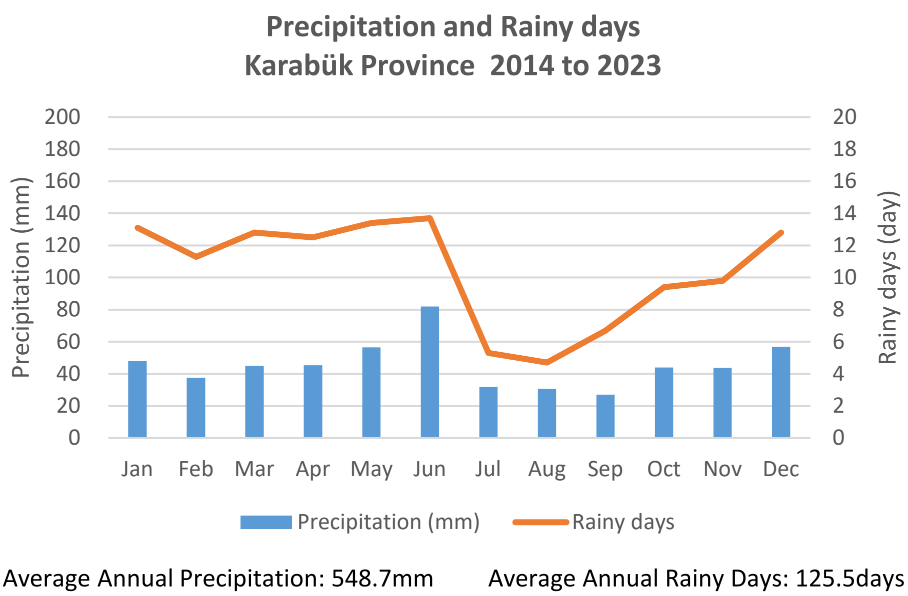


Source: JST prepared based on data on MGM Website[12]

Figure 2-16 Köppen Climate Classification in Türkiye (1991-2020)

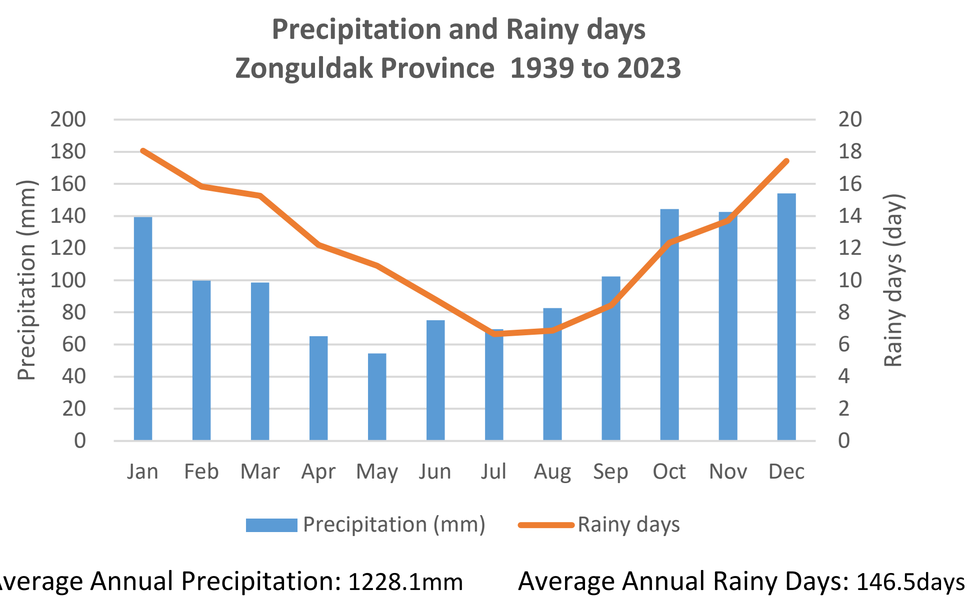
[11] https://www.mgm.gov.tr/veridegerlendirme/yagis-raporu.aspx?b=k#sfB (Accessed November 19, 2024)

[12] https://www.mgm.gov.tr/iklim/iklim-siniflandirmalari.aspx (Accessed November 19th, 2024)



Source: JST prepared based on data on MGM Website[13]

Figure 2-17 Monthly Precipitation and Number of Rainy Days in Karabük Province



Source: JST prepared based on data on MGM Website[14]

Figure 2-18 Monthly Precipitation and Number of Rainy Days in Zonguldak Province

From the above, it was understood that the disaster risks in the railway section are "slope collapse" and "rock fall disaster" due to mountainous areas, and “flooding of rivers crossing the railway line due to heavy rain".

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[13] https://mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=KARABUK (Accessed November 27, 2024)
[14] https://mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=ZONGULDAK (Accessed November 27, 2024)

2.2.2 Risks Posed by Sinkholes to the TCDD High-Speed Rail Line in the Konya Region

At the time of the initial on-site survey and investigation in February 2024, the TCDD high-speed rail section around Konya and Karaman was not included in the target section for an on-site demonstration. In response to a subsequent request from TCDD, it was decided to conduct an on-site demonstration in the TCDD high-speed rail section where sinkholes have occurred in the surrounding area (Figure 2-19). Due to the occurrence of subsidence and cracks in the ground near TCDD high-speed rail tracks, TCDD is concerned that there is a risk of sinkholes occurrence along the railway line.

Source: Google Maps with additions by JST

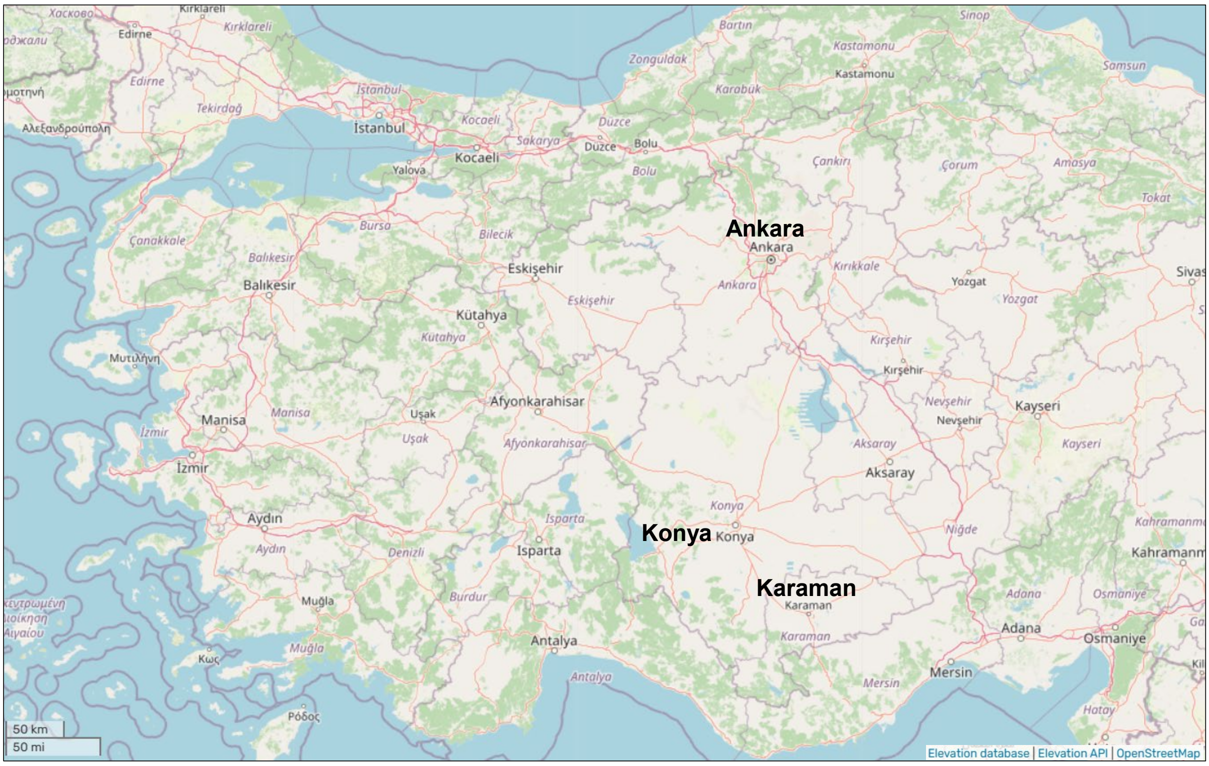
Figure 2-19 Example of Sinkhole in Karapınar District, Konya Province

Konya Province is adjacent to the south of Ankara Province, and its central city, Konya, is located about 230 km south of the nation capital, Ankara (Figure 2-20). Sinkholes occur frequently in Konya Plain area.[15]

Sinkholes are localized subsidences caused by the dissolution of soluble bedrock in limestone landscapes. The main factors that activate sinkhole occurrences are geology, hydrogeology, irrigation, precipitation, climate, land use change, and urbanization. The recent increase in occurrence of sinkholes is considered to be due to climate change, drought, and large amounts of groundwater abstracted for irrigation (lowering groundwater levels). Water-soluble rocks below the surface (such as limestone, carbonate rocks, and salt rocks) dissolve in water, creating voids that lead to the formation of sinkholes. As a result of a drop in the groundwater level, cavities within the rocks are no longer filled with water,

15 Surge in 'Turkey's granary' sinkholes imperils agriculture, Euronews https://www.euronews.com/my-europe/2024/09/06/surge-in-sinkholes-in-turkeys-granary-endangers-agriculture (Accessed April 7, 2025)

reducing hydrostatic pressure and causing the rocks to lose their buoyant support, which leads to the formation of sinkholes. Sinkholes vary in size and depth, ranging from a few meters to hundreds of meters. Signs that a sinkhole is about to occur include cracks in the ground and buildings leaning or cracking, but sometimes sinkholes occur without any warning sign.[16]



Source: OpenStreetMap with additions by JST

Figure 2-20 Locations of Konya and Karaman

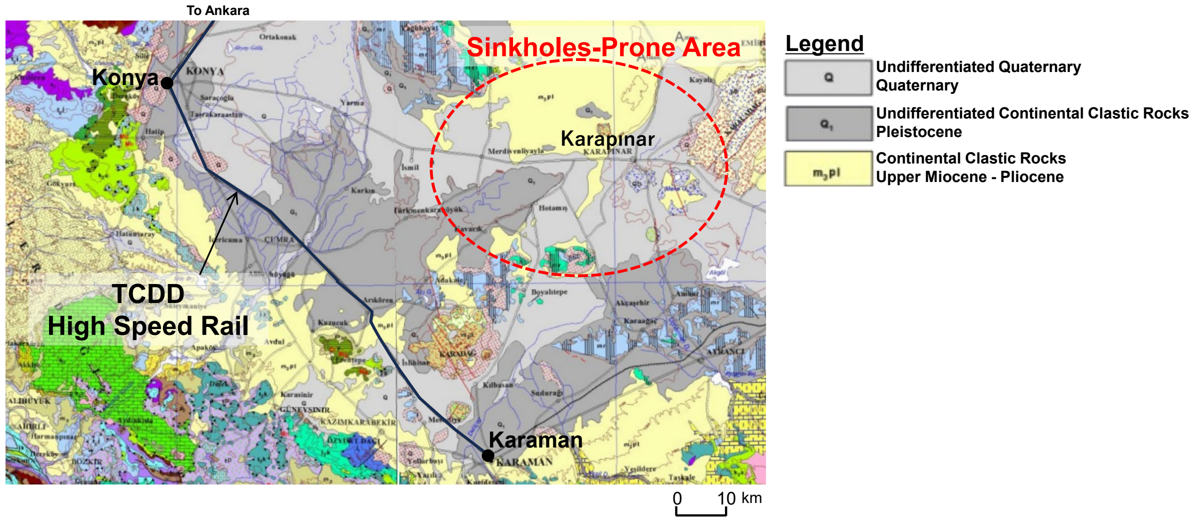
The Karapınar district of Konya Province has seen a number of sinkholes. The geological characteristic of the Karapınar district is its thick carbonate bedrock which is prone to sinkholes. The bedrock consists of Triassic and Jurassic marbles and dolomites, overlain by Jurassic and Cretaceous dolomitic lime stones, which form an important aquifer, unconformably overlain by Cretaceous pelagic lime stones, sandstones, and shale intercalations. Neogene-Miocene sedimentary and volcanic rocks overlie the Cretaceous rocks unconformably which form another important aquifer, and Pliocene andesite and basalt volcanic rocks overlie all the rocks. Marl formed by the influence of plants is interlayered by the limestone, and the decomposition of the marl results in the formation of the cavities.[17]

The geological classification by geological map around Konya and Karaman is shown in Figure 2-21. Sinkhole-prone areas and areas along the TCDD high-speed rail have similar geology. In recent years, not only the number of sinkholes occurring but also the areas where they occur have been expanding.[16]

[16] Information about the Sinkholes, Sinkhole Application Research Centre, Konya Technical University https://www.ktun.edu.tr/en/Birim/Index/?brm=7scBzLffw8qGvf0OCz3nOg== (Accessed April 7, 2025)

[17] Fatih Sarı et al, Evaluating sinkhole formation with multicriteria decision analysis: a case study in Karapınar-Konya, Turkey, Arabian Journal of Geosciences 2021

It is considered that the possibility of sinkholes occurring along the TCDD high-speed rail is also increasing.



Source: JST prepared based on data in General Directorate of Mineral Research and Exploration (MTA) "1:500,000 Scale Geological Map of Turkey", 2002

Figure 2-21 Geological Classification by Geological Map

2.3 Railway Accidents Caused by Natural Disasters in the Past

As described in 2.2, it can be presumed that the risks of slope hazards and flooding of rivers are already apparent in Türkiye. These risks are presented by statistics on rail accidents caused by natural disasters in the past. UEIM, an organization under MOT, has recorded statistics on serious accidents in each traffic mode, including railway. In the mobilization in June 2024, JST interviewed UEIM on past railway accidents caused by natural disasters. As of June 2024, two railway accidents caused by natural disasters were recorded since 2015. (This excludes the derailment of stationary vehicles due to the Türkiye-Syria earthquake in 2023.) Slope hazards and ballast washout by rainfall triggered both accidents mentioned above. Under Turkish legislation, UEIM can only investigate events defined as accidents. Therefore, the above statistics do not contain incidents not defined as accidents. UEIM commented that there were probably also many near-miss incidents.

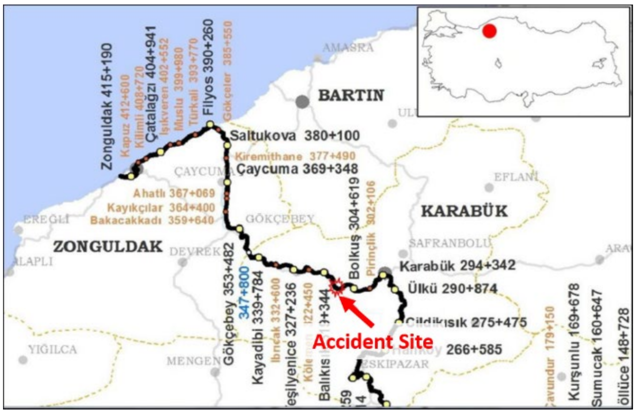
UEIM provided recommendations, including measures to prevent recurrence, based on the investigations into the above two cases (2016, 2018). It is unclear whether these recommendations have been implemented because UEIM cannot afford personnel to follow the implementation of these recommendations. Besides, their recommendation does not have legal authorization to mandate the implementation.

Regarding the above two accidents, UEIM concluded that neither accident resulted from the driver nor any staff-related mishap. Nevertheless, it also confirmed that the relevant staff, including the driver, are being sued for the 2018 accident.

JST collected the following information from UEIM's investigation reports.

(1) Derailment Due to Landslides After Rainfall (occurred in 2016)

- Date: 01:30, November 6, 2016
- Location: Karabük Province, Yenice district, between Balıkısık and Bolkuş stations, point 311 km 650 m



Source: UEIM

Figure 2-22 Location of the Accident Site (2016)

- Injury/Loss of Life : No fatalities
- Damage/Loss in Infrastructure : 120,743.44 TL
- Damage/Loss to Vehicles and Cargo: 141 tons of coal (4 freight wagons derailed)

Source: UEIM

Figure 2-23 Damage to Railway Vehicles

- Impact on operations :

Three passenger trains and one freight train were cancelled due to the closure of the section for 13 hours.

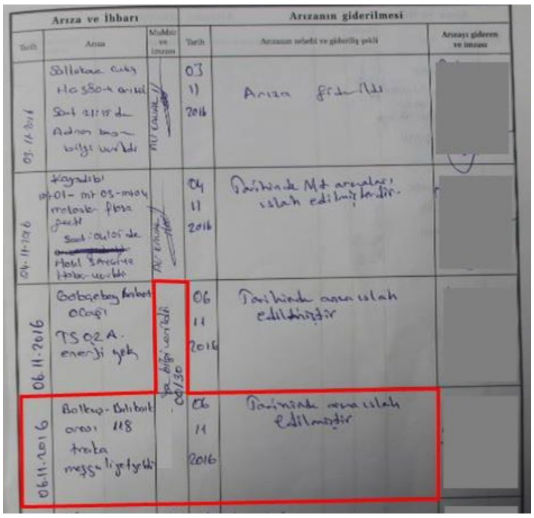
- Overview of the case

The train 24231, running between Balıkısık and Bolkuş, collided with a rock (estimated to be 60-70 tons) on the track at a speed of 39 km/h. The train 24231 turned 90 degrees horizontally to the valley side, derailed, and came to a stop. As a result, the locomotive and four freight wagons derailed.

The CTC at Karabük station was aware of an anomaly in the signalling system of the section before the accident occurred at about 00:30. (Figure 2-24) (Note: The UEIM document stated that the section was in a "Busy" state. JST presumes that a break in the track circuit caused the unauthorized short circuit due to a landslide.)

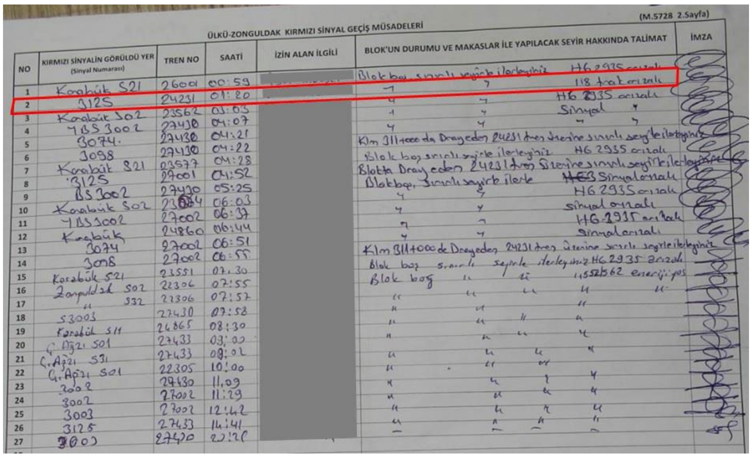
At the time, a new signalling system was being installed in this section, and the signal system experienced failure frequently. The maintenance staff also received this failure report. However, the maintenance staff judged it as a regularly occurring failure.

The maintenance staff responded that the signalling system was new and had frequent faults and that they would investigate and resolve the failures in the morning. At that time, the CTC system was not fully functional due to its newness and multiple faults. The maintenance staff stated that the failure would be examined and resolved the following morning. As a result, the dispatcher at CTC had to judge that it was a recurring failure and instructed train 24231 to pass the stop signal of the BS-3125 signal, which controlled the approach to the section (Figure 2-25).



Source: UEIM investigation report

Figure 2-24 Failure Records at the CTC Center in Karabük at the Time of the Accident



Source: UEIM investigation report

Figure 2-25 Recording of Permission to Enter a Signal with Stop Aspect by the Dispatcher

■ Recommendations for accident prevention:

At the time of the accident, this section was under the upgrading work of its outdated facilities.

Since the 2000s, maintenance staff had been reduced. In this situation, TCDD removed highly hazardous rocks near the track. However, slope management was insufficient. It was also confirmed that the cause of the accident was not falling rocks but slope collapse.

In addition, according to TCDD regulations, the dispatcher did not have the authority to mobilize the maintenance staff for site inspections. Furthermore, the manual for emergency situations did not clearly define the procedure of each unit. As a result, the maintenance staff allowed the train to enter without checking the site.

Based on the collected information, the UEIM suggests the following in its investigation report.

- ✓ Clarify the chain of command and authority in the event of a failure or abnormality.
- ✓ In the event of a failure or abnormality, establish a scenario from beginning to end and clarify the response procedures and the roles of each unit.
- ✓ Consider the deployment of disaster prevention systems that integrate landslide and falling rocks detection devices (sensors) and signalling devices.
- ✓ Conduct regular and efficient maintenance of civil engineering structures, including preventive maintenance.

(2) Derailment Due to a Track Bed Ballast Washout (occurred in 2018)

- ■ Date: 17:15, July 8, 2018
- ■ Location: Tekirdağ Province, Çorlu District, Balabanlı-Çorlu Station, 161 km 955 points

Source: UEIM investigation report

Figure 2-26 Location of the Accident Site (2018)

- ■ Injury/Loss of Life: 25 dead, 268 serious and minor injuries.
- ■ Damage/Loss in Infrastructure: 1 signal equipment box, high-voltage cables and signalling cables were damaged.
- ■ Damage/Loss to Vehicles and Cargo: 6 passenger wagons were derailed, 5 of which became irreparable.
- ■ Impact on operations: 23 freight trains and 7 passenger wagons were cancelled.

■ Overview of the case

The train 12703, which was going from Uzunköprü to Halkalı (Istanbul), departed from Balabanlı station with 342 passengers. When approaching the 110 km/h accident site, the locomotive experienced a vertical jolt and passed the site. Then, the rear bogie of car 1 derailed, and cars 2 to 5 derailed completely and overturned. Moreover, after the derailment of the other cars, car 6 stopped on a tilt at a 45-degree angle (Figure 2-27).

A culvert was installed at the accident site. Between 14:00 and 15:30 that day, the area recorded 32.4mm of rainfall, equivalent to 5% of the annual rainfall in the area. JST presumes that this localized heavy rainfall dammed the culvert and caused the ballast on the track bed to be washed away (Figure 2-28). This data was recorded at MGM's automatic observatory station located in Muratlı near the accident section.

Source：UEIM investigation report

Figure 2-27 Post-Accident Situation

Source: UEIM investigation report

Figure 2-28 Culvert's Condition (Immediately After the Accident)

■ Recommendations for accident prevention:

The accident section is flat, with the tracks along the meandering Cholle River and multiple culverts crossing the tracks in the accident section.

The culvert where the accident occurred had been installed almost 145 years ago. TCDD inspects the culvert twice a year as specified in the manual. TCDD inspected the culvert in May 2018 before the accident. This inspection showed that the culvert channel was normal, and no repair work was required.

On the other hand, in June 2018, TCDD expected an unusual amount of rainfall during the summer.

However, rainfall at the accident site was localized, and there was no information from TCDD or any outside observatory. The headway between the previous train and the accident train was 7 hours. Therefore, the O&M departments were not properly informed of the excessive rainfall.

As a result, the accident occurred on the first train after damming the culvert, which caused the track bed ballast washout.

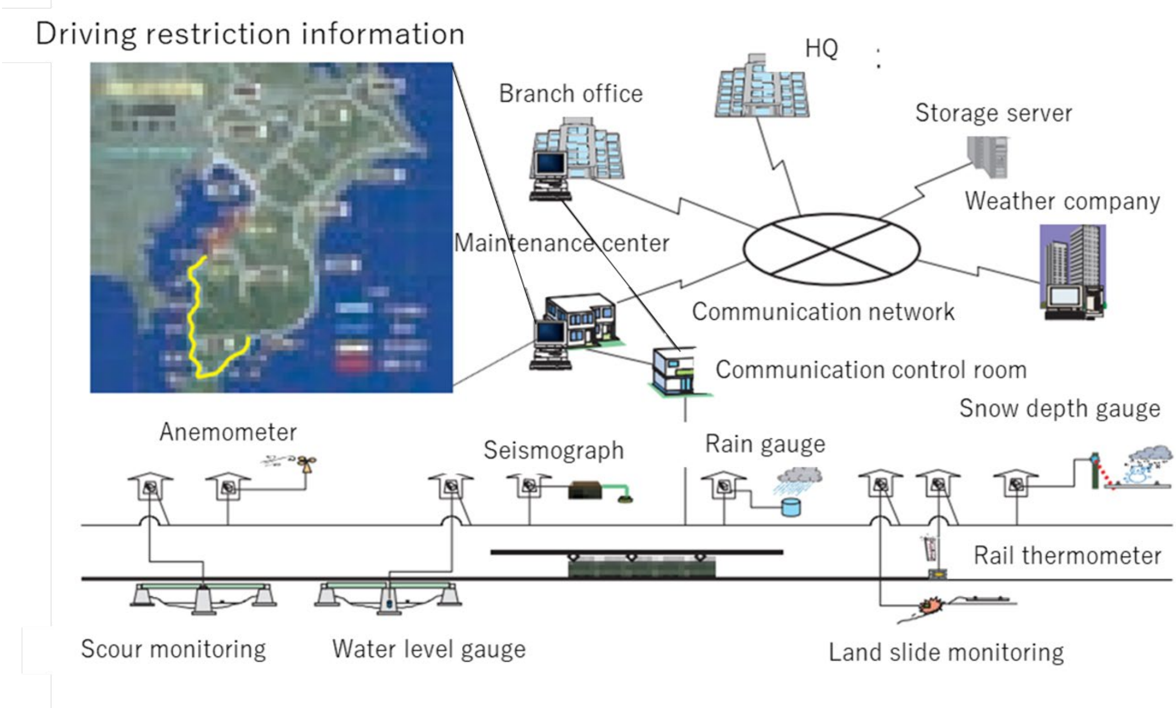
The UEIM suggests the following in its investigation report based on the collected information.

- ✓ Demonstrate a system that uses sensors to detect displacement and destruction of civil engineering structures.
- ✓ Based on weather and hydrologic research, re-examine culverts and bridges over 100 years old for channel flow. In addition, take measures if necessary.
- ✓ Establish an information-sharing system with MGM. In addition, MGM should provide TCDD with basic education and training on weather data interpretation and utilization.
- ✓ Develop procedures and regulations for dealing with localized summer rainfall.
- ✓ Strengthen and revise the organizational structure to perform the maintenance as determined in the manual.

Chapter 3 Considerations for Implementing the Disaster Management/Prevention Systems

3.1 Scope of the Disaster Management/Prevention Systems

JR East uses the Prevention of Disaster Alarm System (hereinafter PreDAS) as a disaster prevention system. This system transmits data on observation devices for disaster prevention. It uses seismometers, anemometers, and fallen rock detectors, installed along railway lines to detect natural disasters, and issues regulations and sounds warnings, enabling speed regulations and suspension of operation (Figure 3-1). At the same time, it is also possible to manage the inspection of railway and civil engineering facilities after the issuance of regulations.



Source: JRE

Figure 3-1 Overview of the PreDAS

On the other hand, because PreDAS is a system that has been used since 1990, all devices are connected to communication lines and power lines, and the initial investment and maintenance costs are high. Accordingly, JST selected the Zero-Energy IoT Series system manufactured by OKI Electric Industry Co., Ltd., which has been used by JR East, as a natural disaster prevention system (NDPS) that meets the requirements of a disaster risk measure for TCDD in the Survey.

As countermeasures against landslides, falling rocks, and floods, which are identified as high priority in section 2.1, this system constantly monitors the situation at the site at risk of disaster from remote locations. It is expected that the effects of the disaster will be minimized by enabling prompt monitoring of the situation in the event of a disaster. It is also anticipated to reduce the number of times inspectors are dispatched to dangerous sites in the event of a disaster. This helps ensure the safety of maintenance and management operations. Ease of implementation and high reliability are required as important requirements for the full-scale implementation of the system by TCDD. To give some background, it is difficult to connect power and communication on the ground in mountainous areas where there is a risk of disaster. Doing so would require a large initial investment when laying the cables. For this reason, this NDPS system eliminates the need for power and wiring and ensures ease of installation by supporting operation by battery or solar power generation and data transmission by wireless network. In addition, high reliability is required for tilt and water level measurement, sufficient performance for imaging, environmental resistance that allows long-term operation even in outdoor locations, and stable operation of the system. Therefore, the selection of this system was based on the condition that the system has a track record of use among Japanese railway companies such as JR East.

A diagram of the system to be installed in this study is shown in Figure 3-2.

Source: Prepared by survey team

Figure 3-2 Diagram of the Structure of the Natural Disaster Prevention System to be Installed in This Survey

3.2 Technical Specification of the System

In this survey, a railway natural disaster prevention system will be introduced to mitigate the risks of river flooding caused by slope collapse, rock fall, and heavy rainfall. The expected specifications for the system construction are as follows.

(1) Common Requirements

The monitoring system shall allow remote monitoring of the measurement items shown in (2) from the display terminal (PC, mobile communication device, etc.) of the administrator of the structure to be monitored by a single system (software) via the Internet, etc.

(2) Measurement Categories

- Natural frequency
- Angle of tilt
- Still images (high-sensitivity cameras)

- Water level
- Condition of the equipment (battery voltage, temperature inside the equipment, radio wave intensity)

(3) Configuration and Quantity of Equipment

The monitoring system shall consist of the following devices and quantities.

- Acceleration sensor device
- Highly sensitive camera
- Ultrasonic water level measuring device

(4) Equipment Requirements

A) Acceleration sensor device

The acceleration sensor device shall meet the following specifications.

a.) It shall have a function for measuring the natural frequency of bridge piers. The acceleration sensor device shall be capable of extracting and transmitting peak frequencies in real time from micromotion data on bridge piers.

b.) Angle of tilt measurement shall be supported. The unit shall be 0.01 degrees or less and the measurement accuracy shall be ±0.1 degrees or less. It shall be possible to measure the angle of tilt in two vertical directions simultaneously.

c.) Even when the tilt angle is measured with a 10-minute cycle, it must be able to be operated for 3 months or longer without the need for external power supply or battery replacement.

d.) In addition, the product shall meet the specifications in the following table (Table 3-1).

Table 3-1 Requirements for Acceleration Sensors

Item		Required specification
Measurement function	Natural frequency	Measurement axis: 3 axes
		Measurement range: ±2G
	Angle of tilt	Orientation: Vertical two directions
		Unit: not more than 0.01 degrees
		Accuracy: within ±0.1 degrees
Dimensions (mm)		Total length of three sides is 300 mm or less.
Weight		1 kg or less
Signal communication	Standards	LTE or subgiga band wireless
	Frequency of transmission	More than once every 10 minutes
Equipment	Temperature and	To monitor the temperature and humidity inside the

Item		Required specification
monitoring	humidity sensor	equipment
	Voltage measurement	Battery voltage drop monitoring
Man-machine	LED display	1 green for startup check and 1 red for error notification
Interface	Maintenance port	USB, etc.
Power supply conditions	Power source	Battery drive
Environmental conditions	Temperature-humidity condition	-20 to 60℃, 10 to 95%RH
	Storage temperature and humidity conditions	-20 to 60℃, 10 to 95%RH
	Dust and waterproof resistance	IP65 equivalent
Environmental measures		Compliant with RoHS
Burning resistance		Equivalent to UL94-V0
Appearance		

Source: Prepared by JST

B) Highly sensitive camera

The high-sensitivity camera equipment shall meet the following specifications.

a.) It shall support the capturing of still images and the image data shall be transmitted by the LTE communication function.

b.) It shall support high-sensitivity shooting functions and must be able to capture clear images without illumination even in a dark environment of 0.01 lux.

c.) High-sensitivity camera equipment shall not require an external power supply due to built-in solar power generation panels, etc.

d.) Even when the image shooting and LTE transmission is performed at 30-minute intervals, the equipment shall be able to be operated continuously for 9 days or longer under conditions of no sunlight.

e.) Integrated equipment with a high-sensitivity camera unit, solar power generation panel, rechargeable battery, and LTE communication unit shall all be built in. The dimensions shall be 1,000 mm or less in total (excluding protrusions) and easy to install.

f.) Other items shall meet the specifications in the following table (Table 3-2).

Table 3-2 Requirements for High-Sensitivity Camera

Item		Required specification
Shooting mode		Still image shooting and auto high-sensitivity shooting
Brightness		Can be used with 0.01 lux (clear shooting without lighting)
Maximum number of pixels		Full HD equivalent (1920 x 1080)
Shooting timing		Shooting at regular intervals
Image angle		109 degrees or more horizontally and 59 degrees or more vertically
Compression system		JPEG
Dimensions (mm)		The total length of three sides is 1,000 mm or less.
Weight		6 kg or less
Signal communication	Standards	LTE communication
	Frequency of transmission	At least once every 30 minutes
Equipment monitoring	Temperature and humidity sensor	To monitor the temperature and humidity inside the equipment
	Voltage measurement	Battery voltage drop monitoring
Man-machine interface	LED display	1 green for startup check and 1 red for error notification
	Maintenance port	USB, etc.
Power supply conditions	Power source	Photovoltaic power generation and secondary batteries
	Operating conditions	Operation for up to 9 days in a continuous, non-sunny environment
Environmental conditions	Temperature-humidity condition	-20 to 60°C, 10 to 95%RH
	Storage temperature and humidity conditions	-20 to 60°C, 10 to 95%RH
	Dust and	IP65 equivalent

Item		Required specification
	waterproof resistance	
Environmental measures		Compliant with RoHS
Burning resistance		Equivalent to UL94-V0
Appearance		

Source: Prepared by survey team

C) Ultrasonic water level measuring device

Ultrasonic water-level gauges shall meet the following specifications.

a.) Ultrasonic water level measurement shall be possible and water level measurement data shall be transmitted by the LTE communication function.

b.) The accuracy of the ultrasonic water level measurement shall be ±1 cm or less.

c.) Ultrasonic water-level gauges shall not require external power supply due to built-in solar power panels.

d.) Even when the transmission by ultrasonic water level measurement and LTE communication is performed at 10-minute intervals, the equipment shall be able to be operated continuously for 9 days or longer under conditions of no sunlight.

e.) Integrated equipment with built-in ultrasonic water level measuring unit, solar power generation panel, rechargeable battery, and LTE communication unit. The dimensions shall be 1,000 mm or less in total (excluding protrusions) and easy to install.

f.) In addition, the product shall meet the specifications in the following table (Table 3-3).

Table 3-3 Requirements for Ultrasonic Water Level Measuring Equipment

Item		Required specification
Measurement method		Ultrasonic reflection type
Measurement range		The distance between the measuring unit and the water surface is 1 to 10 meters.
Measurement accuracy		±1cm
Dimensions (mm)		Total length of three sides is 1,000 mm or less (excluding protrusions)
Weight		6 kg or less
Signal communication	Standards	LTE communication
	Frequency of transmission	At least once every 10 minutes

Item		Required specification
Equipment monitoring	Temperature and humidity sensor	To monitor the temperature and humidity inside the equipment
	Voltage measurement	Battery voltage drop monitoring
Man-machine interface	LED display	1 green for startup check and 1 red for error notification
	Maintenance port	USB, etc.
Power supply conditions	Power source	Photovoltaic power generation and nickel hydride batteries
	Operating conditions	Operation for 9 consecutive days of non-sunshine
Environmental conditions	Operating temperature and humidity conditions	-20°C to 60°C, 10%-95%RH, Measurement unit-5°C to 50°C
	Storage temperature and humidity conditions	-20 to 60°C, 10 to 95%RH
	Dust and waterproof resistance	IP65 equivalent
Environmental measures		Compliant with RoHS
Burning resistance		Equivalent to UL94-V0
Appearance		

Source: Prepared by survey team

3.3 Challenges for Introduction of Disaster Prevention System

3.3.1 Challenges in TCDD

Since TCDD has no track record in operating railway NDPS, the development of standards in the event of a disaster, such as operational regulation guidelines, will be an issue. JST listed the items that need to be considered when drafting the guidelines, as follows.

・Development of standards such as railway operation regulation guidelines
・Insufficient information about the structure, such as the loss of the design drawing of the structure

・Information about the surrounding environment such as geology
・Selection/establishment of a technical review body

3.3.2 Challenges in the Equipment

(1) Compliance With Laws and Regulations in Türkiye

In Türkiye, it is necessary to comply with laws and regulations equivalent to those of EU member states, and equipment must comply with them. Details are provided in Table 4-4.

(2) Connectivity of Wireless Communication Services

The system uses wireless communication services provided by Turkish telecommunications carriers as a wireless network. It was necessary to confirm that the site where the measuring equipment of the railway disaster prevention system is installed is within the range of the wireless communication service provision area. In this survey, the JST confirmed the coverage of wireless communication services at candidate locations for the introduction of sensors with the cooperation of Turkcell, Türkiye's largest mobile communication provider.

(3) Enhancing Awareness of the Impact and Effectiveness of Remote Monitoring

It is necessary to make TCDD aware of the benefits of remote monitoring so that tangible efforts are made to introduce the disaster prevention system to enhance disaster prevention capabilities through use of the system.

However, TCDD has not implemented monitoring equipment designed for disaster prevention or regular condition monitoring, and the effectiveness of devices currently in trial or pilot stages has not been validated. Therefore, the survey aimed to promote an understanding of the effectiveness of such systems by conducting on-site demonstration experiments of remote monitoring systems at several TCDD locations with specific disaster risks.

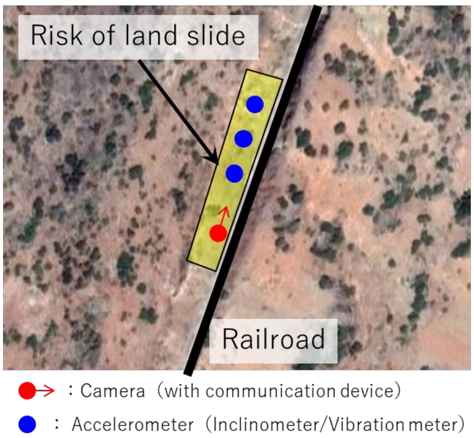
During the on-site demonstration period, the equipment successfully detected a rockfall and transmitted the data to the cloud system, thereby demonstrating the effectiveness of both the equipment and the monitoring network.

Chapter 4 On-Site Demonstration of the Disaster Monitoring/Alert System on the Operating Line in TCDD

4.1 Target

4.1.1 Slope Collapse Detection

A fixed-point camera for visual inspection (e.g., still image shooting at normal 6-hour intervals) and some acceleration sensors are placed on a slope where there may be rock falls or landslides. When the acceleration sensor detects an abnormality exceeding a certain value, the fixed-point camera switches to high-frequency shooting (e.g., shooting still images at 1-minute intervals) at the same time as issuing a warning to the control point, making it possible for the administrator to visually check it almost in real time.



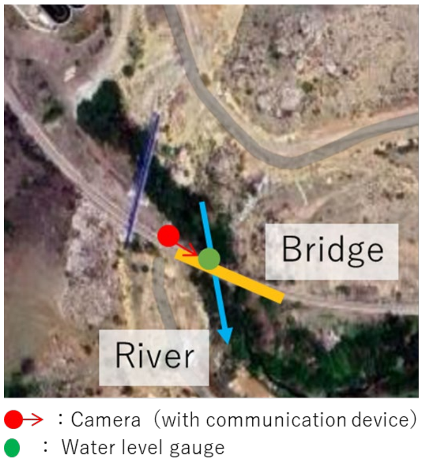
Source: Prepared by survey team

Figure 4-1 Image of Slope Collapse Detection System

4.1.2 River Water Level Detection

The railway disaster prevention system for floods is similar to the disaster prevention system for detecting rocks and ground slopes. In addition to fixed-point cameras for visual inspection, water level gauges for measuring the amount of water are installed on culverts and bridge piers. If the water level gauge detects an abnormality exceeding a certain value, visual check with a fixed-point camera is enabled.

In addition, it will be possible to share the display terminal with the disaster prevention system that detects rock fall and ground slope.



Source: Prepared by survey team

Figure 4-2 Image of River Water Level Detection

4.1.3 Sinkhole Occurrence Detection

Fixed-point cameras for visual inspection (e.g., capturing still images at 6-hour intervals under normal conditions) and multiple accelerometers are installed along railway lines at high risk of sinkhole occurrence. As with slope collapse detection, if the acceleration sensor detects an abnormality that exceeds a certain value (threshold), a warning (alert) is issued to the management location. The fixed-point camera switches to high-frequency shooting (e.g., shooting still images at 1-minute intervals) at the same time as issuing the warning, making it possible for the administrator to visually check it almost in real time. This also makes it possible to share the display terminal.

Source: Prepared by survey team

Figure 4-3 Image of Sinkhole Detection System

4.2 Selection of On-Site Demonstration Area

In this survey, JST conducted on-site demonstration experiments along the Karabük–Filyos section and the Ankara–Karaman high-speed railway section, which had previously undergone disaster screening.

4.2.1 Items to Consider When Selecting a Location for the Demonstration Experiment

The following items were examined in selecting the locations.

Items related to the selection of sections

- Estimated magnitude of damage from railway accidents
- Accessibility of the survey team (distance from Ankara)*
- Importance of railway sections (number of runs)

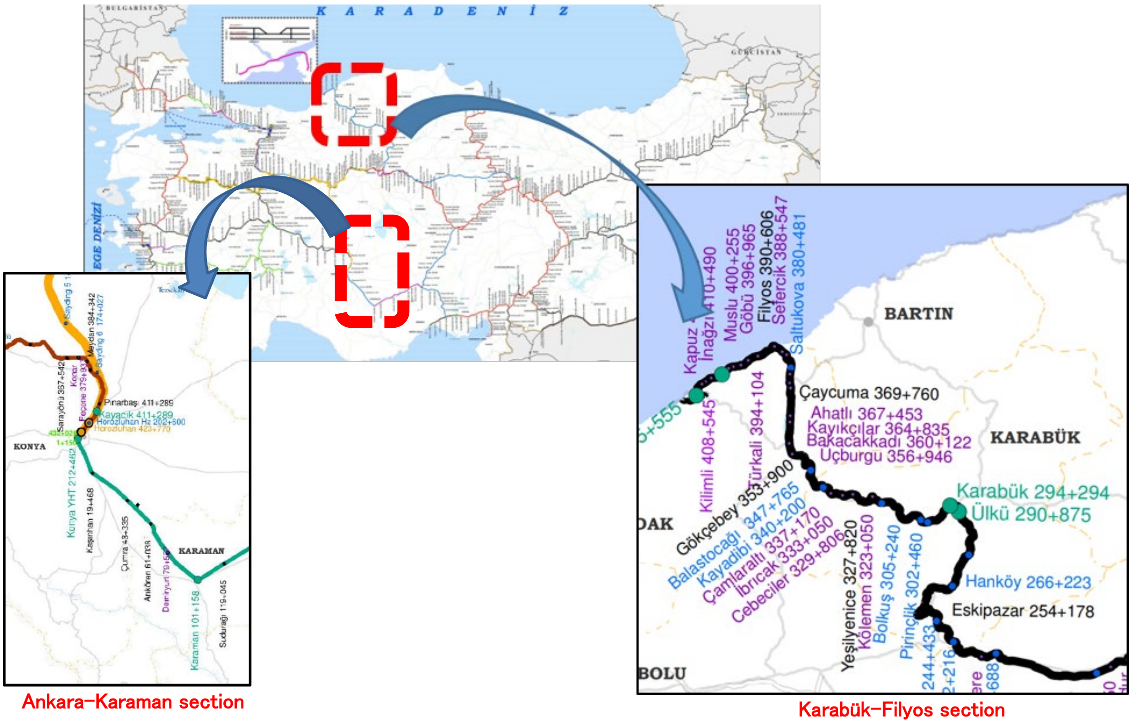
Items related to selection of points

- High likelihood of railway accidents due to disasters
- Communication environment*
- Construction environment

*The marks indicate the items of priority.

4.2.2 Existing Condition of the Section for On-Site Demonstration

In the Survey, JST decided to carry out the demonstration Karabük - Filyos section and Ankara – Karaman section (high-speed rail line) based on the request from the TCDD side and the on-site survey.



Source: TCDD

Figure 4-4 Position of the Section for On-Site Demonstration

(1) Karabük - Filyos Section

The section is highly important as it has to cope with high transport demand of up to 60 trains (including freight and passengers) per day.

An accident occurred on the section in January 2024, and as of February 2024, operations were being temporarily stopped for 4-5 hours per day to allow time to clear away fallen rocks.
Given the above, carrying out major infrastructure work without stopping train operations is unrealistic. In addition, TCDD considers that stopping the service is not an option as the station connecting to the port of Filyos is at the end of the section. An overview of the section in question is given below.

Table 4-1 Overview of the Section (Karabük- Filyos)

Item	Description
Distance	96 km
No. of trains	60 trains/day (Including 16 passenger trains)
Axle load	22.5 ton
Operating speed	80km/h
Signaling system	ETCS 1 (Eight passing loop stations)
Operation control	CTC (Single control station operates signals, etc. at each station)

Source; JST

The section has 750 m of passing loop facilities at each station to enable longer train configurations. TCDD installed cameras transmitting information to CTC in areas carrying out rock fall removal work. It was confirmed that there were no regulations for disaster detection using those cameras and train operation control utilizing them.

(2) Ankara – Karaman Section

The section is an important high-speed railway line for passenger transport, and further extension is planned for the future. Last year, unevenness in the track led to the discovery of a large cavity under the track, and it was pointed out that there is a risk of sinkholes occurring along the track similar to those occurring around Konya, and investigations are still ongoing. Trains are continuing to operate, with measures being taken such as monitoring equipment and slowing down.

Table 4-2 Overview of the Section (Ankara – Karaman)

Item	Description
Distance	320 km
No. of trains	24 trains/day (10 trains on Konya - Karaman section)
Axle load	16.2 ton (HT65000 series)
Operating speed	250 km/h (200km/h on Konya - Karaman section)
Signaling system	ETCS 2 (ETCS 1 on Konya - Karaman section)

Source; JST

4.3 On-Site Demonstration Plan

4.3.1 Results of Installation Location Selection

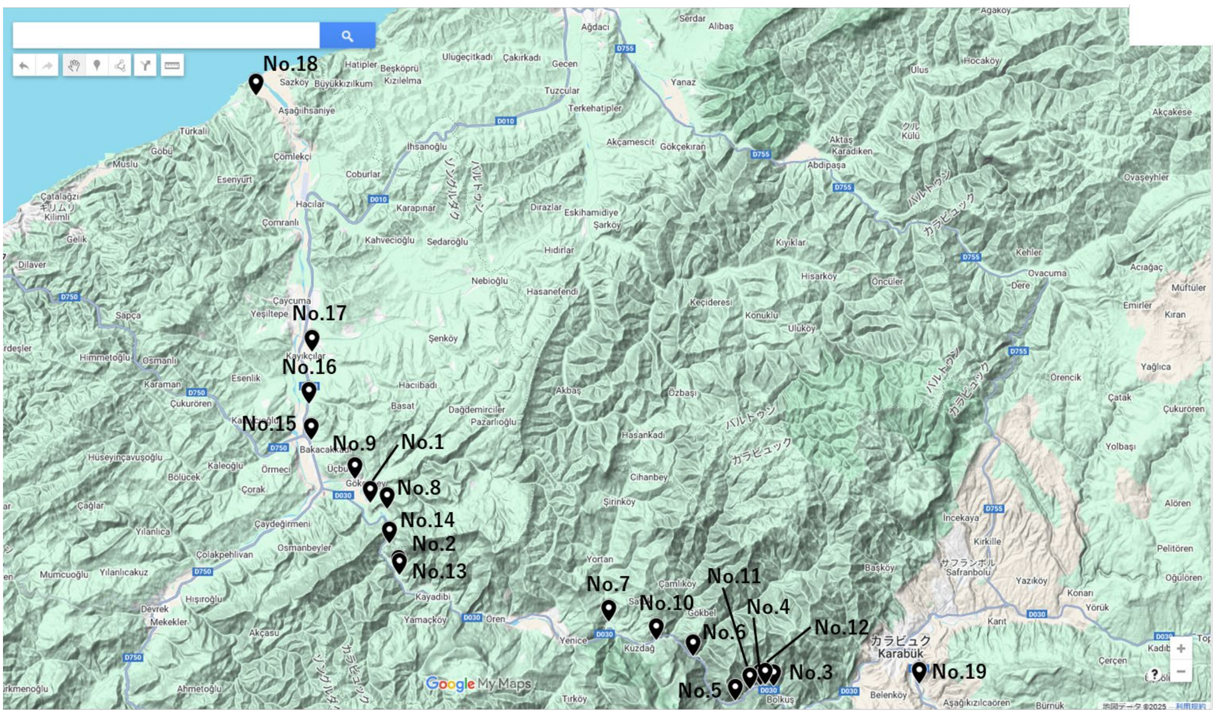
JST inspected the target section together with the maintenance team from the TCDD local office, and identified candidate locations that were considered to be high risk and would be most effective for monitoring. These were then analyzed and examined in Japan, while at the same time conducting detailed surveys and communications tests on-site. The results are summarized in the table below.

Table 4-3 List of Locations Investigated

No.	Target structure	Type of disaster	Section	Signaling	Workability
1	Cut and shape slope	Landslide	Kayadibi-Gökçebey	High	High
2	Culvert (small)	Track flooding	Kayadibi-Gökçebey	-	High
3	Rockfall barrier on tunnel entrance	Rockfall	Bolkuş-Balıkısık	None	Low
4	Rockfall barrier on rocking wall	Rockfall	Bolkuş-Balıkısık	None	Low
5	Rocking wall 1	Rockfall	Bolkuş-Balıkısık	None	High
6	Rocking wall 2	Rockfall	Bolkuş-Balıkısık	None → High*	High
7	PC bridge	Scouring	Kölemen- Yeşilyenice	Low	High
8	Embankment slope	Railbed collapse	Kayadibi-Gökçebey	-	-
9	Cut slope (shaping and stone retaining)	Landslide	Gökçebey-Üçburgu	High	High
10	RC bridge	Scouring	Pirinçlik-Bolkuş	-	-
11	Rockfall barrier on rocking wall	Rockfall	Bolkuş-Balıkısık	None	High
12	Culvert (dry river)	Track flooding	Kayadibi-Gökçebey	-	-
13	Underground pipe	Railbed outflow	Kayadibi-Gökçebey	None	Low
14	Culvert (canal)	Railbed outflow	Kayadibi-Gökçebey	Low	Low
15	Culvert (middle)	Track flooding	Üçburgu- Bakacakkadı	High	High
16	Embankment slope	Track flooding	Bakacakkadı-Kayıkçılar	Low	High
17	Culvert (large)	Track flooding	Bakacakkadı-Kayıkçılar	Low	High
18	Underground pipe	Track flooding	Derecikören-Gökçeler	None	High
19	Cut slope	Landslide	Karabük-Aşağı Kızılcaören	High	High
20	Cut slope	Ground crack	Polatlı-Selçuklu	None	Low
21	Earthwork 1	Sinkhole	Polatlı-Selçuklu	High	High
22	Embankment slope	Sinkhole	Polatlı-Selçuklu	High	High
23	Earthwork 2	Sinkhole	Kayacık-Meydan	High	High
24	Earthwork 3	Sinkhole	Kaşınhan-Çumra	High	High
25	Earthwork 4	Sinkhole	Çumra-Karaman	Low	High

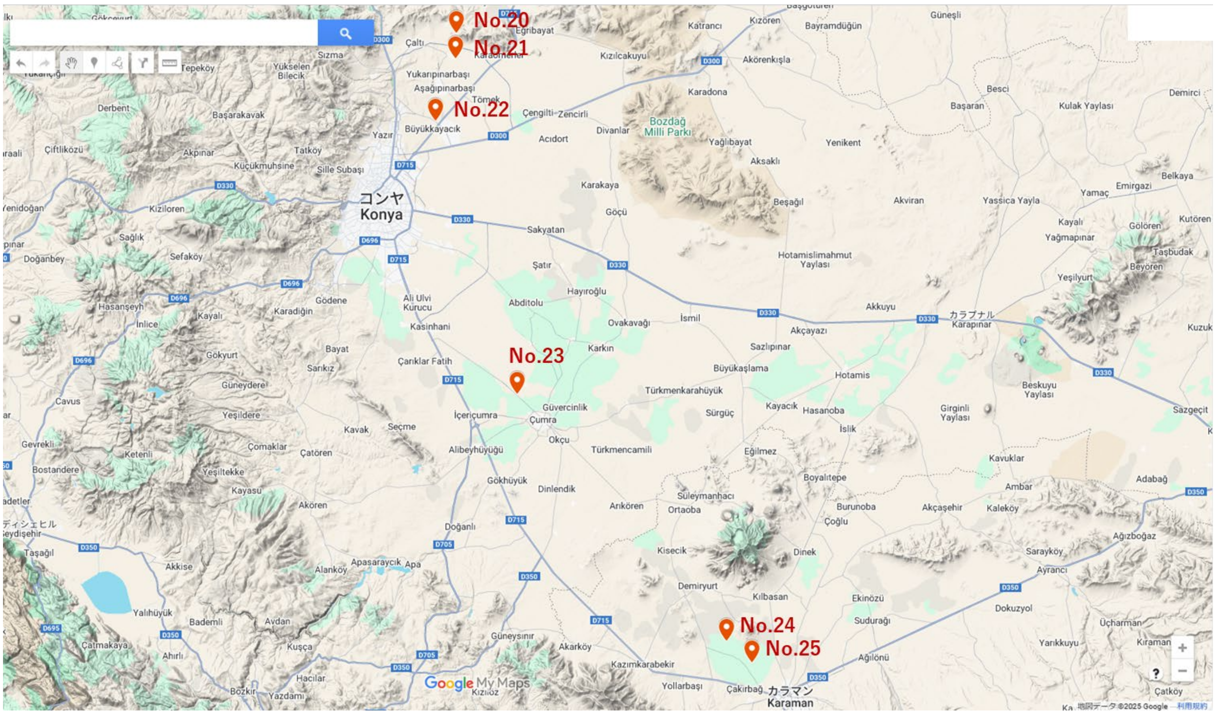
*Based on quick test
Source: JST

Based on the Table 4-3, No. 9 cut slope and No. 15 culvert were selected as the demonstration experiment locations. Additional points are also still under consideration.



Source; Google Maps with additions by JST

Figure 4-5 Location Map of Survey Sites (Karabük - Filyos)



Source; Google Maps with additions by JST

Figure 4-6 Location Map of Survey Sites (Ankara - Karaman)

4.3.2 Installation Location Details

(1) No.6 Rock Slope

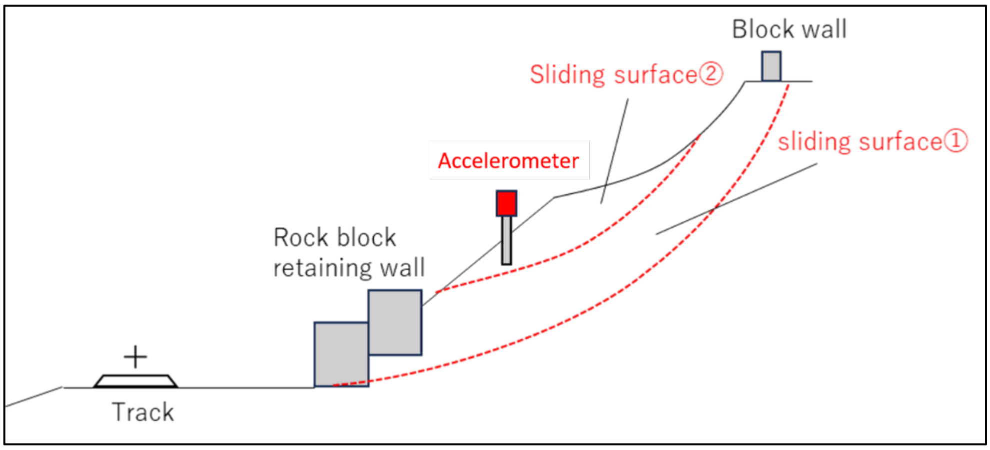
The affected area experienced a rockfall in November 2024, and as a countermeasure, all trains passing through the area are required to stop and slow down. The rock face itself remains unstable, posing a high risk of rockfalls, and effective countermeasures must be implemented. Currently, only regular patrols are conducted by inspectors, and constant monitoring using monitoring equipment is required to ensure safety.

Source; JST

Figure 4-7 Target Rock Slope

(2) No.9 Cut Slope

The affected area experienced a landslide in 2020, and as a countermeasure, slope shaping and stone retaining wall construction have been implemented, but these measures are insufficient and there is still a high risk of slope collapse, making slope monitoring necessary. Currently, only periodic patrols are carried out by inspectors, but the installation of monitoring equipment will enable constant monitoring.



Source; JST

Figure 4-8 Expected Slip Surface

(3) No.15 Culvert (Middle)

The affected area experienced large-scale flooding in 2022, which resulted in train service suspension. Currently, the area relies on reports from residents, and no concrete measures have been put in place. There is no way to observe if flooding occurs at night, so monitoring is necessary. If a train enters a flooded area, there is a risk of derailment or vehicle failure.

Source; Google Maps with additions by JST

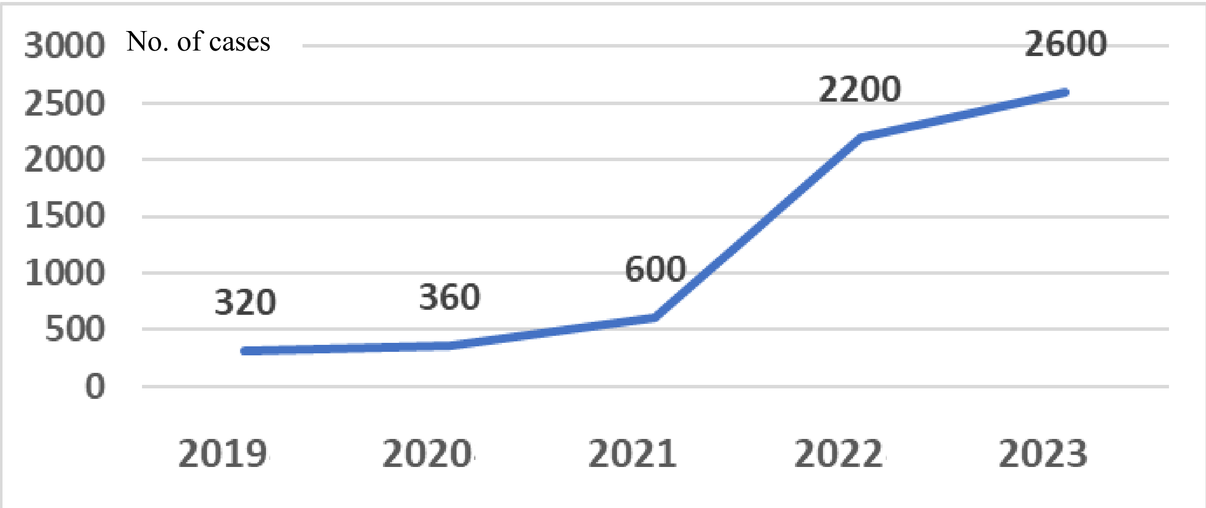
Figure 4-9 Expected Area of Flooding

(4) No.21-26 Sinkholes

The number of sinkholes has been increasing rapidly in the Konya region of Türkiye, and TCDD, which has a high-speed railway line, is being forced to respond to the risk. The main cause is said to be excessive use of groundwater due to a long-term drought, and some analyses suggest that there are signs such as cracks before they occur. In principle, water-soluble rocks (limestone, carbonate rocks, salt rocks, etc.) below the surface dissolve in water, creating voids that lead to the formation of sinkholes. Sinkholes of various sizes have been observed, ranging from small ones 1-2m wide and less than 3m deep to ones over 100m wide and over 60m deep.

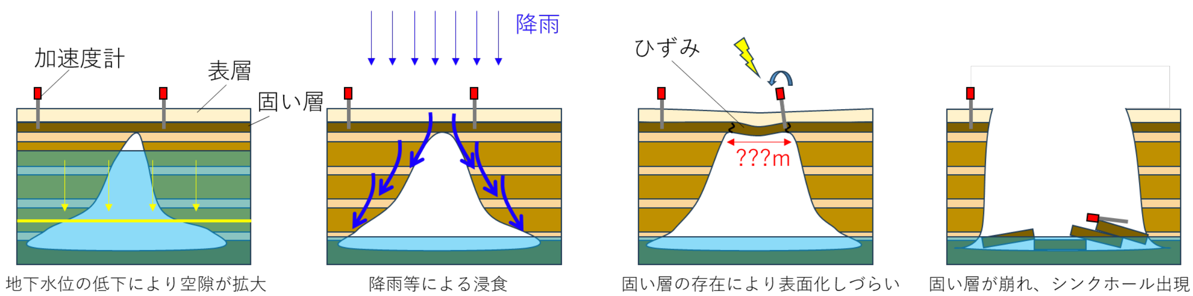
Source: Yasin AKGUL / AFP

Figure 4-10 Sinkhole in Konya Region



Source: JST

Figure 4-11 Changes in the Number of Sinkholes Identified in Konya Region



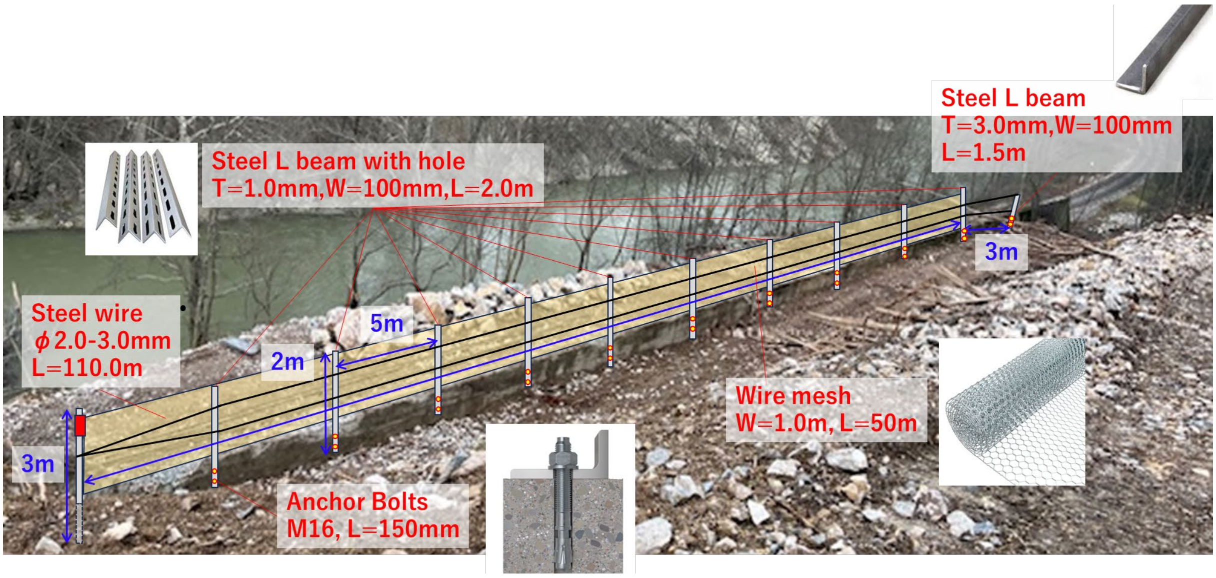
Source: JST

Figure 4-12 Mechanism of Sinkhole Occurrence and Detection System

4.3.3 Installation Plan

(1) No.6 Rock Slope

Monitoring was made possible by installing accelerometers on the end posts of a simple rockfall detection fence. In addition, a pole with an accelerometer was installed halfway up the slope below the rock wall in order to observe its movements. An alarm is issued if the accelerometer exceeds a preset threshold. The threshold setting was decided in consultation with TCDD.



Source: JST

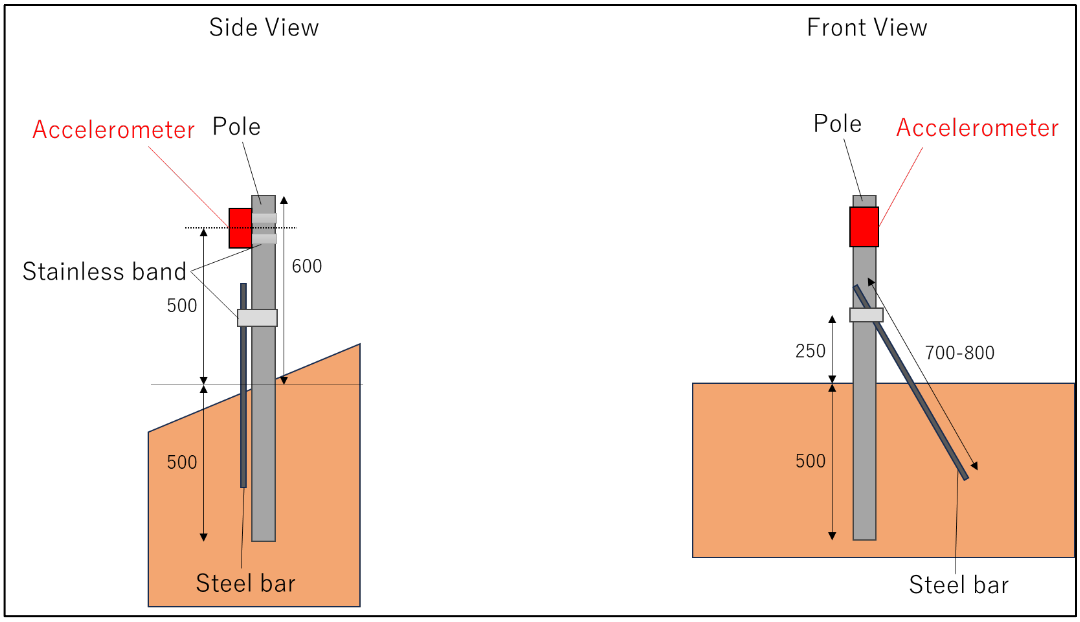
Figure 4-13 Rockfall Detection Network Installation Plan

(2) No.9 Cut Slope

Monitoring will be carried out by installing inclinometers on the surface of moving objects. Small-scale slope collapse has also occurred on the west side of the moving objects (left side of Figure 4-14). This was close to the railway tracks. Therefore, there is a plan to install them on the surface of objects that could potentially move. Changes in the inclination angle due to the movement of the moving objects will be detected, and a warning will be issued if the threshold value is exceeded. At the same time, the camera will switch to high-frequency shooting and inform the control point so that a decision can be made regarding operation of trains through the area. The threshold value will be set in consultation with TCDD.

Source; JST

Figure 4-14 Cut Slope Monitoring Plan

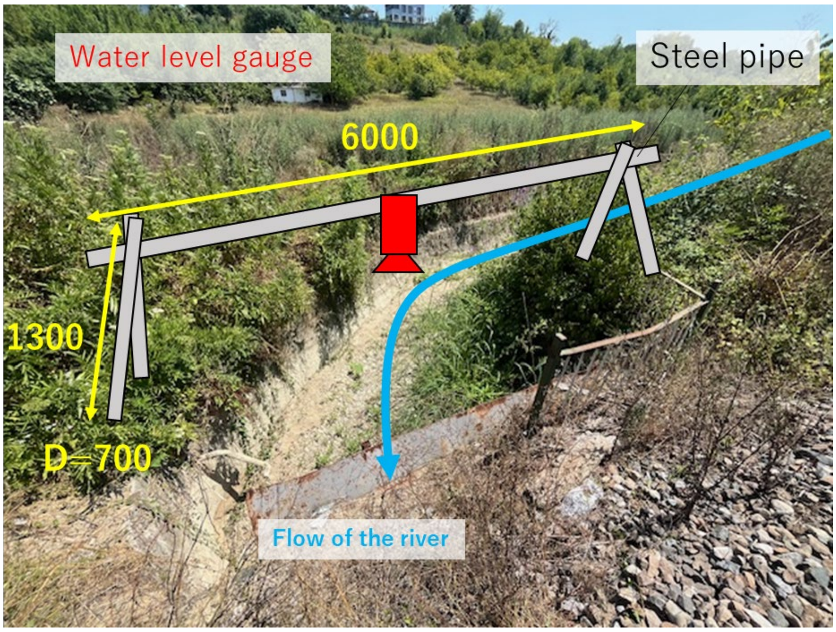


Source; JST

Figure 4-15 Accelerometer Installation Plan

(3) No.15 Culvert

A water level gauge will be installed upstream of the culvert for monitoring. Changes in the water level will be detected and an alarm will be issued if the threshold is exceeded. At the same time, the camera will switch to high-frequency shooting and inform the control point so that a decision can be made regarding operation of trains through the area. The threshold will be set in consultation with TCDD.

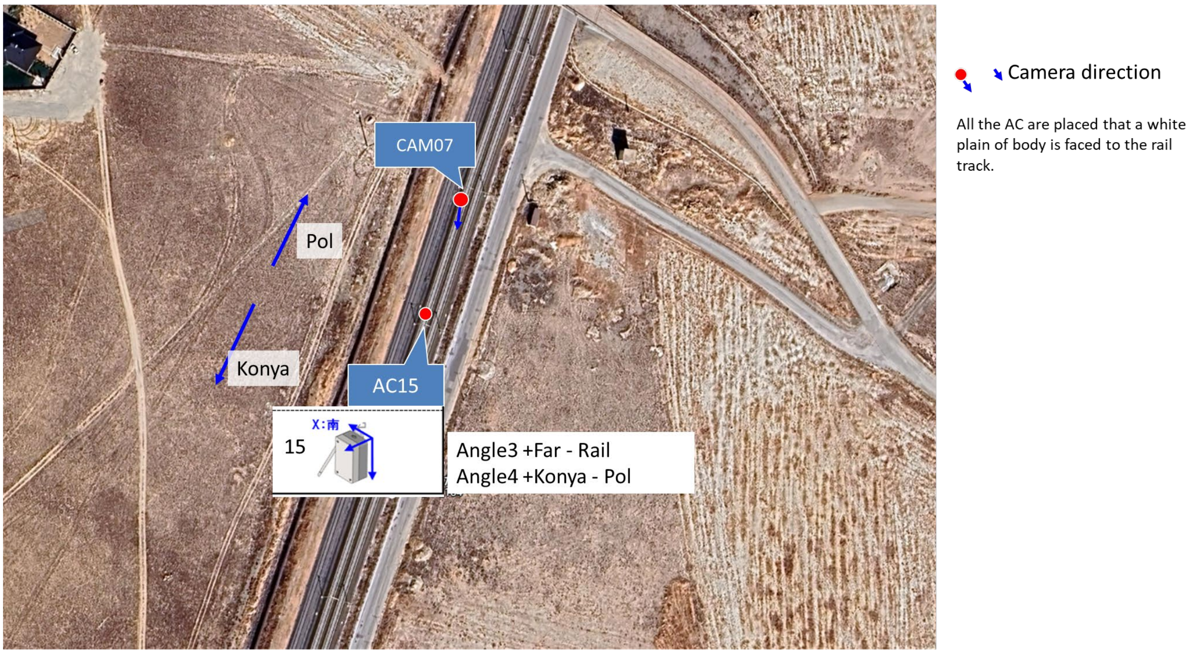


Source; JST

Figure 4-16 Water Level Gauge Installation Plan

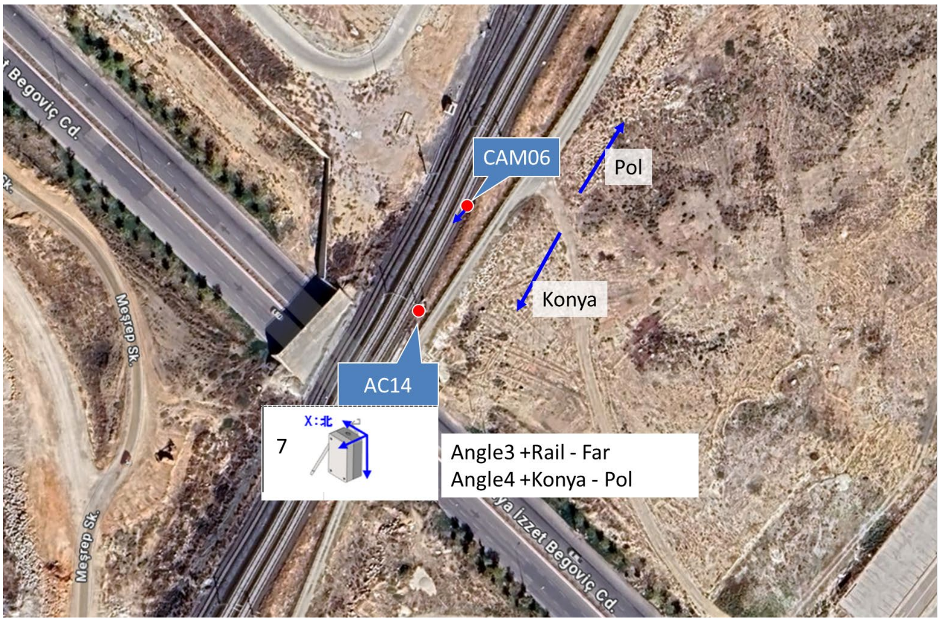
(4) No.21 Earthwork 1 (Sinkhole)

The plan is to plant poles equipped with accelerometers along the tracks in areas deemed to be at high risk of sinkholes in a survey (not disclosed) being conducted by CDD, and to monitor ground surface trends. If the accelerometer readings exceed a preset threshold, a warning will be issued. The threshold settings were decided in consultation with TCDD. (The same applies to (5) to (8) below.)



Source: JST

Figure 4-17 Accelerometer Installation Plan (No.21)



Camera direction

All the AC are placed that a white plain of body is faced to the rail track.

Source: JST

Figure 4-18 Accelerometer Installation Plan (No.21-2)

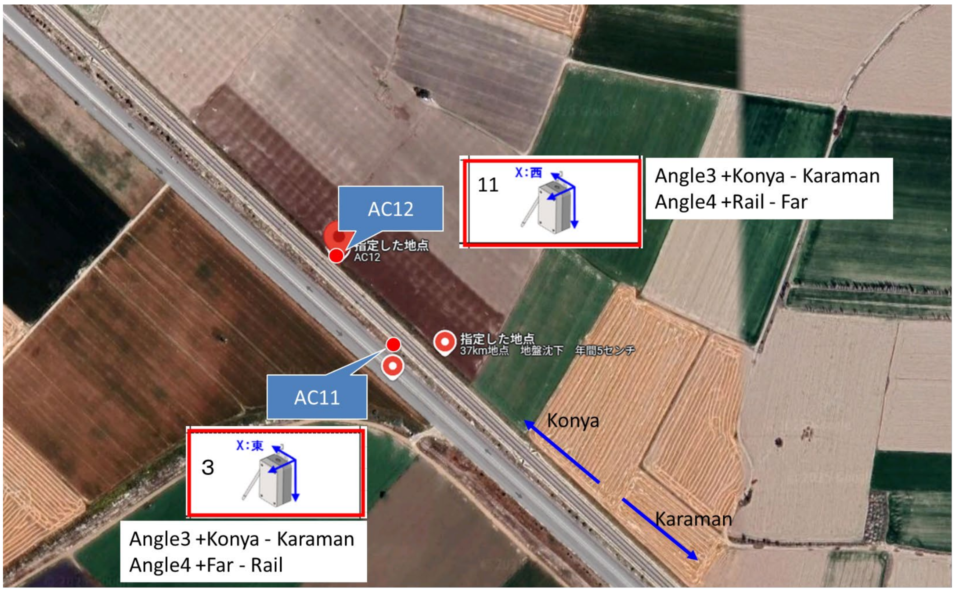
(5) No.22 Embankment Section (Sinkhole)

All the AC are placed that a white plain of body is faced to the rail track.

Source: JST

Figure 4-19 Accelerometer Installation Plan (No.22)

(6) No.23 Earthwork 2 (Sinkhole)

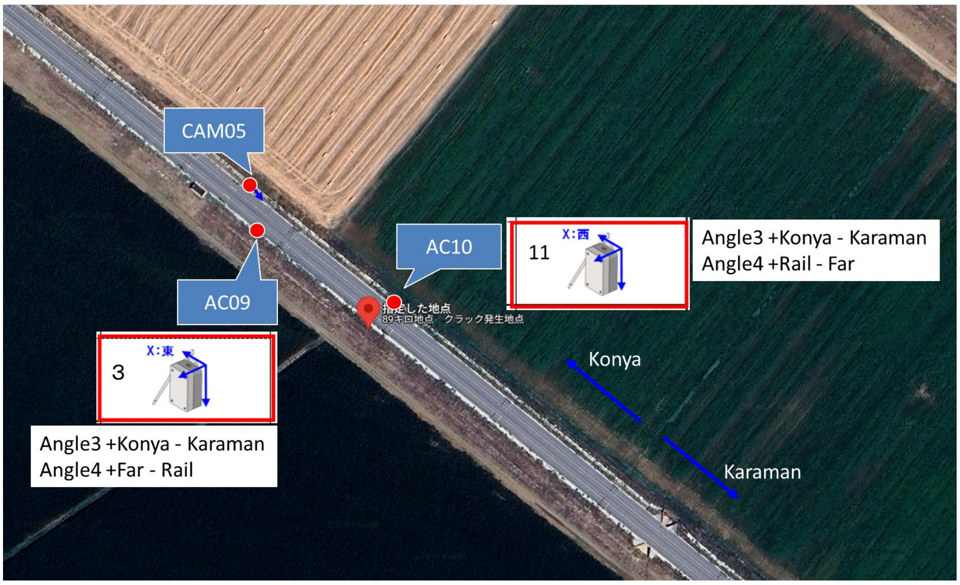


All the AC are placed that a white plain of body is faced to the rail track.

Source: JST

Figure 4-20 Accelerometer Installation Plan (No. 23)

(7) No.24 Earthwork 3 (Sinkhole)



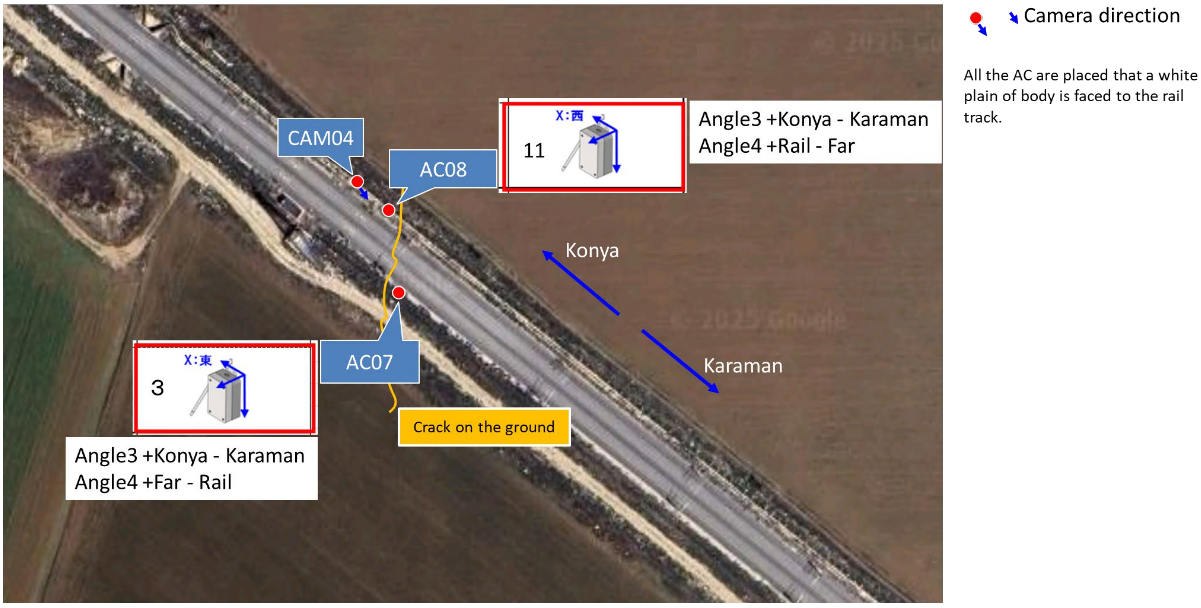
Camera direction

All the AC are placed that a white plain of body is faced to the rail track.

Source: JST

Figure 4-21 Accelerometer Installation Plan (No. 24)

(8) No.25 Earthwork 4 (Sinkhole)



Source: JST

Figure 4-22 Accelerometer Installation Plan (No. 25)

4.4 Regulations in Türkiye in the Development of a Railway Natural Disaster Prevention System

In Türkiye, it is required to comply with laws and regulations equivalent to those of EU member states, and equipment must comply with them. Examples include regulations on radio use and regulations on substances whose inclusion is banned such as RoHS and REACH. It is necessary to declare CE marking and affix CE marking through the implementation of design and testing in compliance with regulations listed in the below table(Table 4-4). In the on-site demonstration, it is possible to partially exempt CE markings by importing as a detection system consisting of sensors and cameras rather than exporting each device. Discussions were held with TCDD about this, and it seems that TCDD has used this method in the past by introducing test equipment from other countries.

Table 4-4 CE Marking Regulations Related to Disaster Prevention System Development

Abbreviation, etc.	Relevant laws and regulations	EU Ref
RED	Radio Equipment Directive	2014/53/EU
Batteries Regs (Turkish WBAC)	Regulation on batteries and waste batteries	(EU) 2023/1542
POPs	Persistent Organic Pollutants Regulation	(EU) 2019/1021
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals Regulation	(EC)1907/2006
RoHS	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Directive	2011/65/EU
PIC	Prior Informed Consent Regulation	(EU)649/2012
WEEE	Waste Electrical and Electronic Equipment Directive	2012/19/EU
Packaging Regs (Turkish WPM)	The Packaging and Packaging Waste Directive	94/62/EC

Source: Prepared by survey team

The domestic laws of Türkiye stipulate negative lists for items not to be imported by TCDD and public organizations including the above-mentioned laws. It was confirmed that the on-site demonstration equipment is not included in the negative list.
JST confirmed that the equipment is not infringement the above laws and regulations.

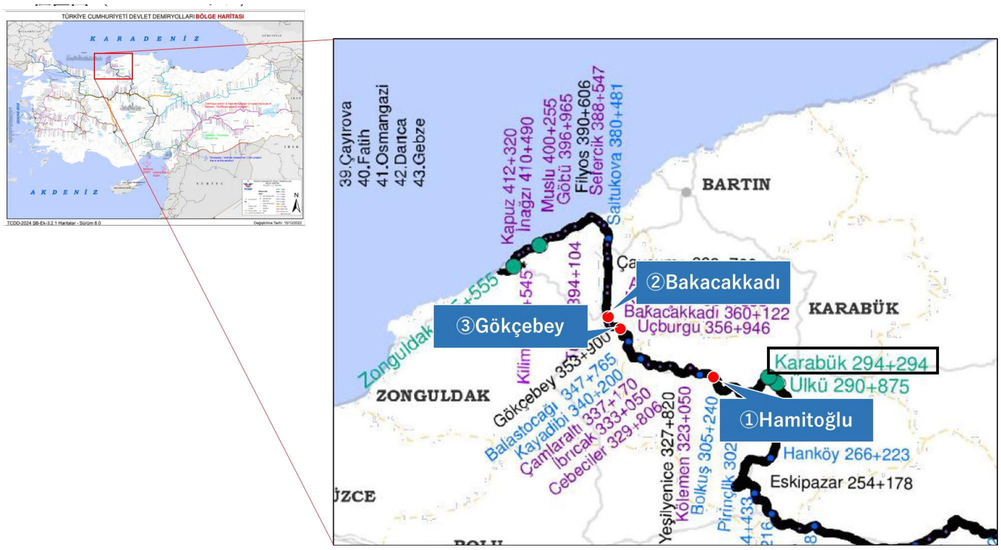
4.5 Result of the On-Site Demonstration

JST carried out the installation work in January and February 2025. TCDD arranged for local workers and equipment for the installation, while the survey team members fine-tuned the location and installation method, and set up the software after the equipment was fixed. The work was generally carried out as planned, and the installation was completed as shown in the table and photos below. Issues that arose during the installation will be discussed later.

Table 4-5 List of Equipment Locations

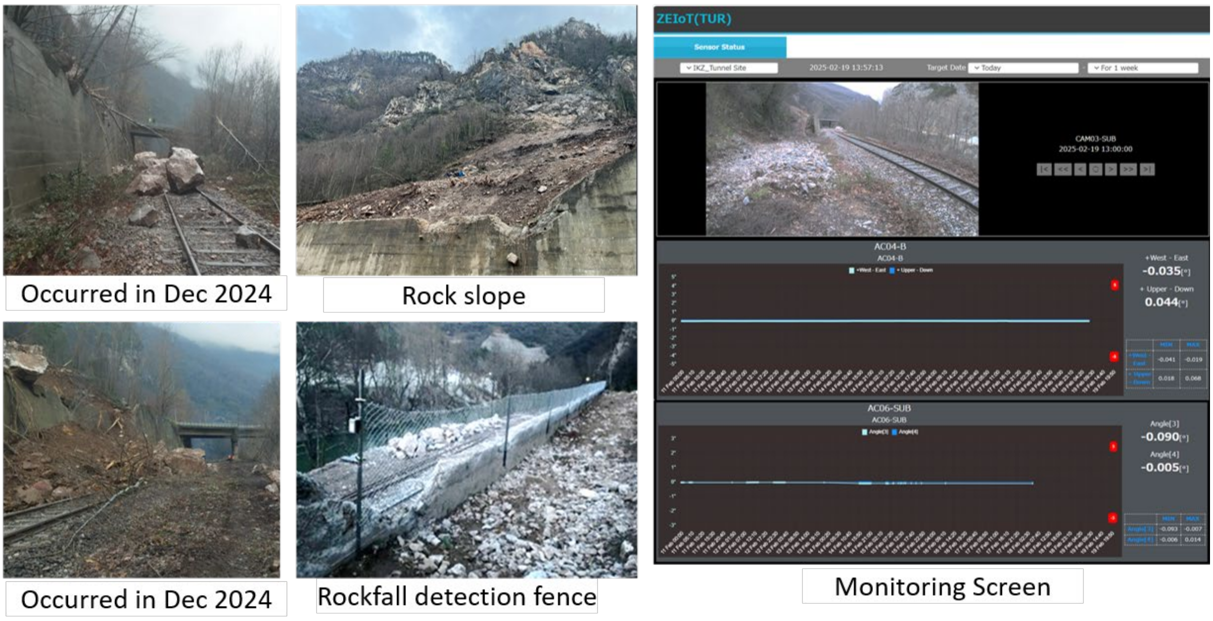
Area	Location	Accelerometer	Camera	Water level gauge
Karabük (1st batch)	No.6 Rock falling in Hamitoğlu	2 pcs*	1pc*	-
	No.9 Cut slope collapse in Gökçebey	3 pcs	1 pc	-
	No.15 Flooded tracks in Bakacakkadı	-	1 pc	1 pc
Konya (2nd batch)	No.21 Land subsidence (sinkhole) near 184km between Pol-Kon	1 pc	1 pc	
	No.22 Land subsidence (sinkhole) near 195km between Pol-Kon	2 pcs	1 pc	
	No.23 Land subsidence (sinkhole) near 37km between Kon-Ka	2 pcs	-	
	No.24 Ground crack (sinkhole) near 89km between Kon-Ka	2 pcs	1 pc	
	No.25 Ground crack (sinkhole) near 94km between Kon-Ka	2 pcs	1 pc	
Total		14 pcs	7 pcs	1 pc

*Including spare units
Source: JST



Source: JST

Figure 4-23 Location of Equipment in Karabük Area

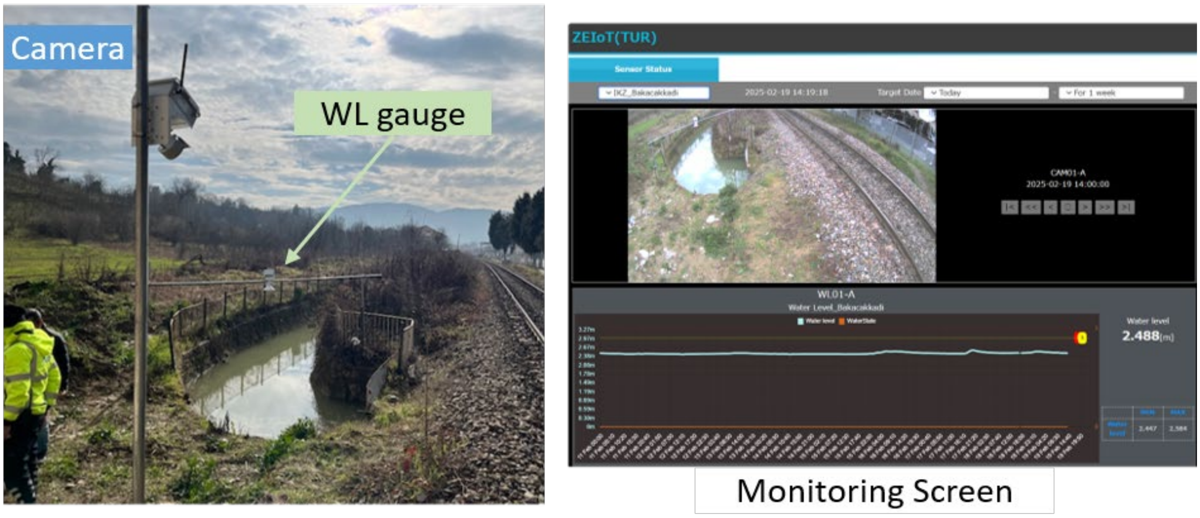


Source: JST

Figure 4-24 No.6 Rock Slope 2 (Installation Status)

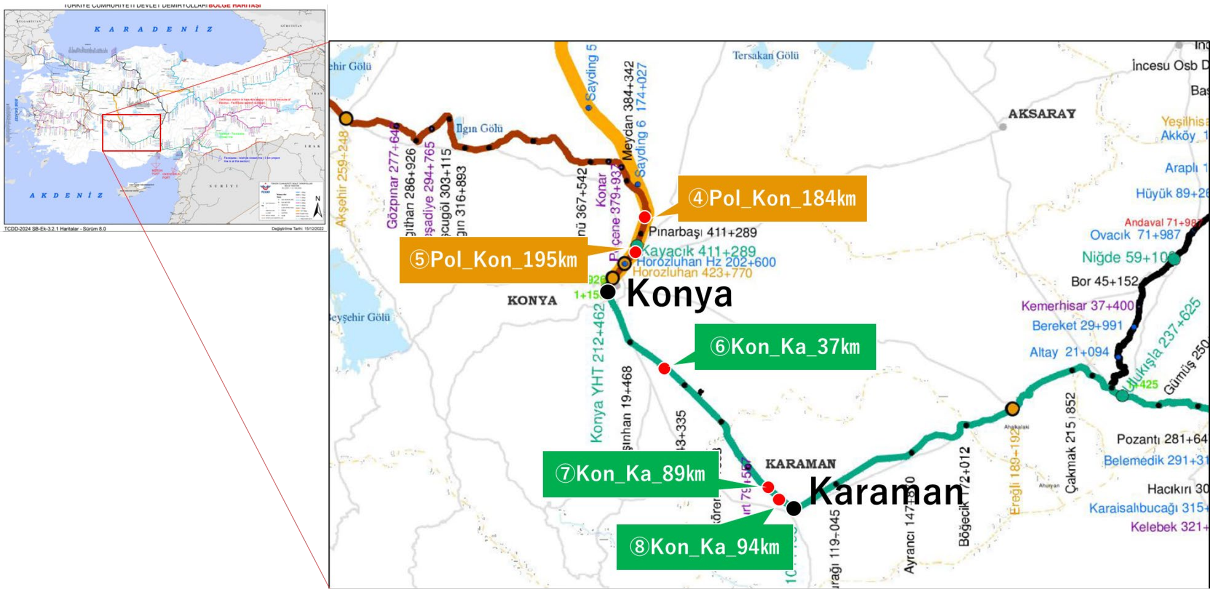
Source: JST

Figure 4-25 No.9 Cut Slope (Shaping and Stone Retaining) (Installation Status)



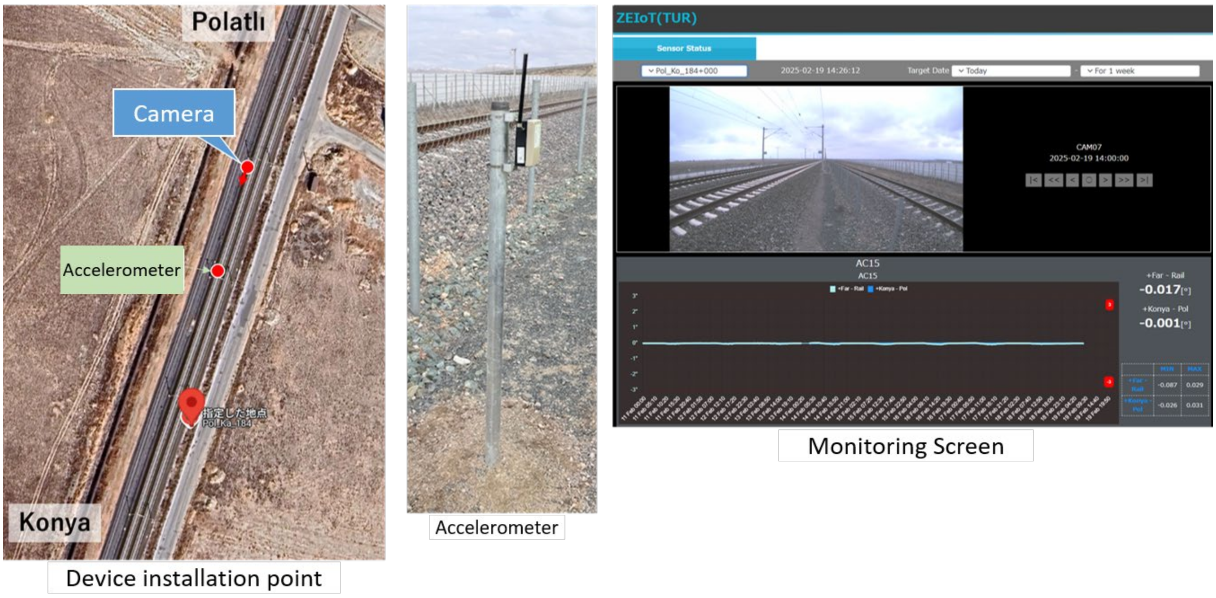
Source: JST

Figure 4-26 No.15 Culvert (Middle Size) (Installation Status)



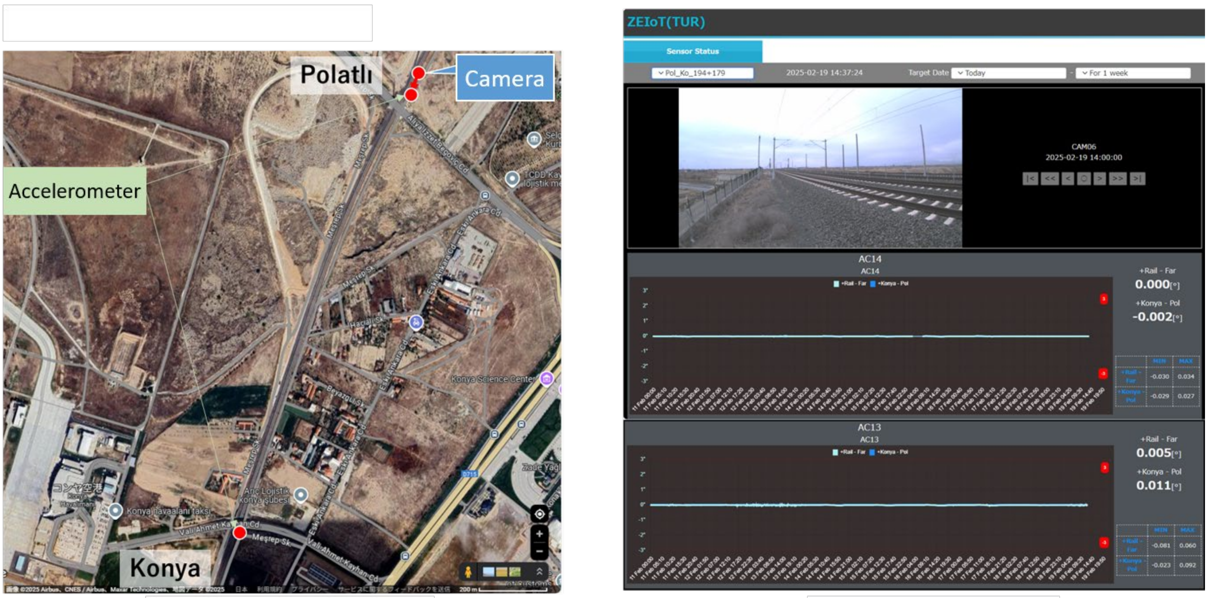
Source: JST

Figure 4-27 Location of Equipment in the Konya Area



Source: JST

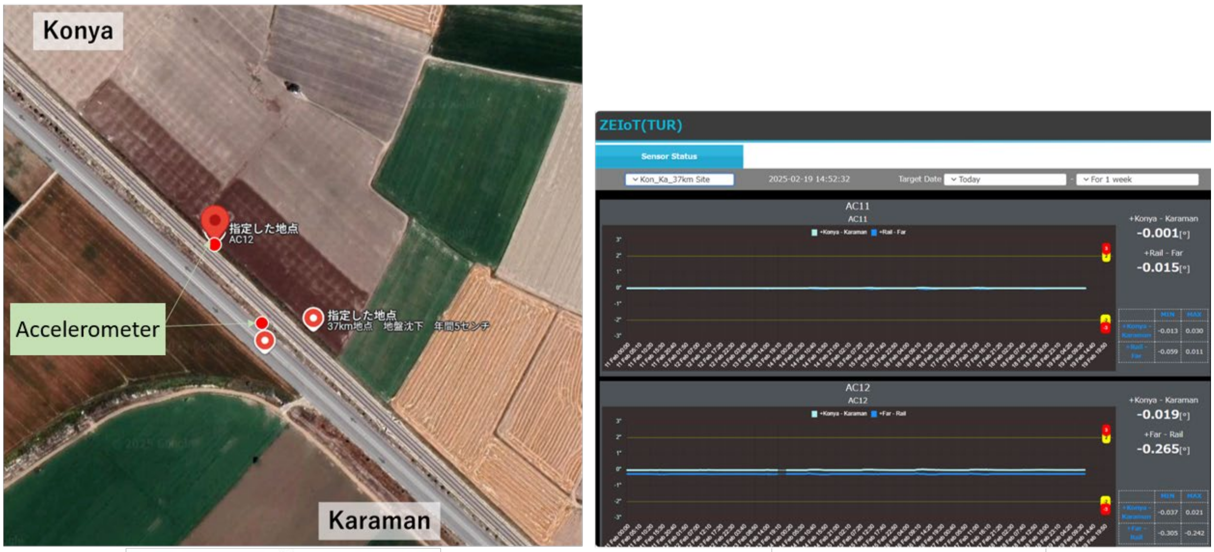
Figure 4-28 No.21 Earthwork 1 (Sinkhole) (Installation Status)



Device installation point　　Monitoring Screen

Source: JST

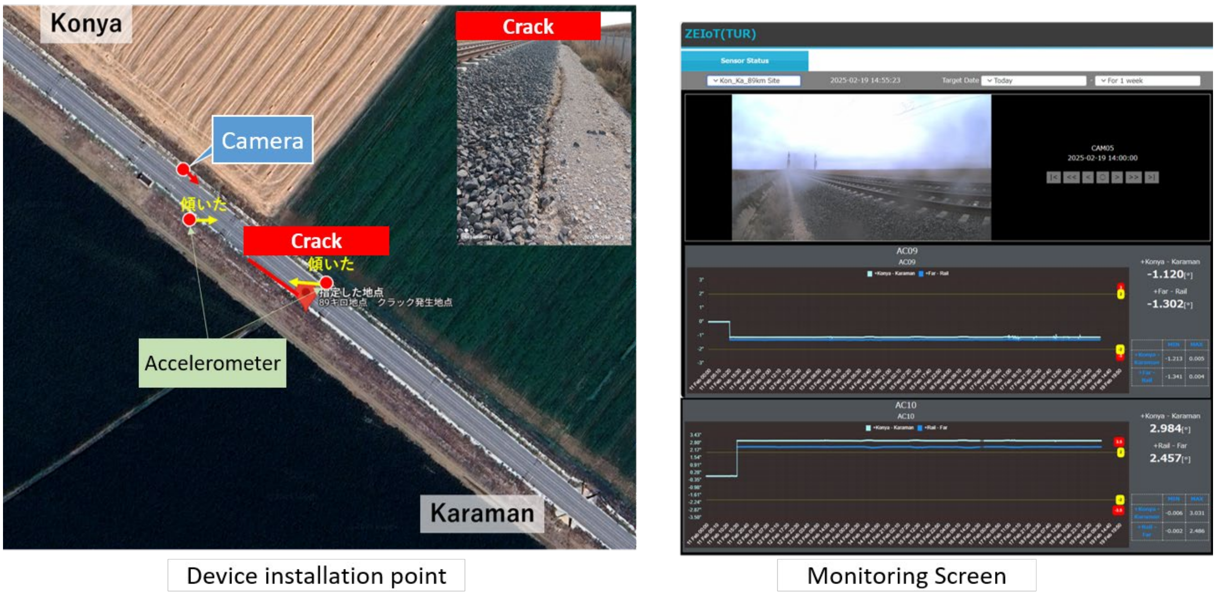
Figure 4-29 No.22 Embankment Section (Sinkhole) (Installation Status)



Device installation point　　Monitoring Screen

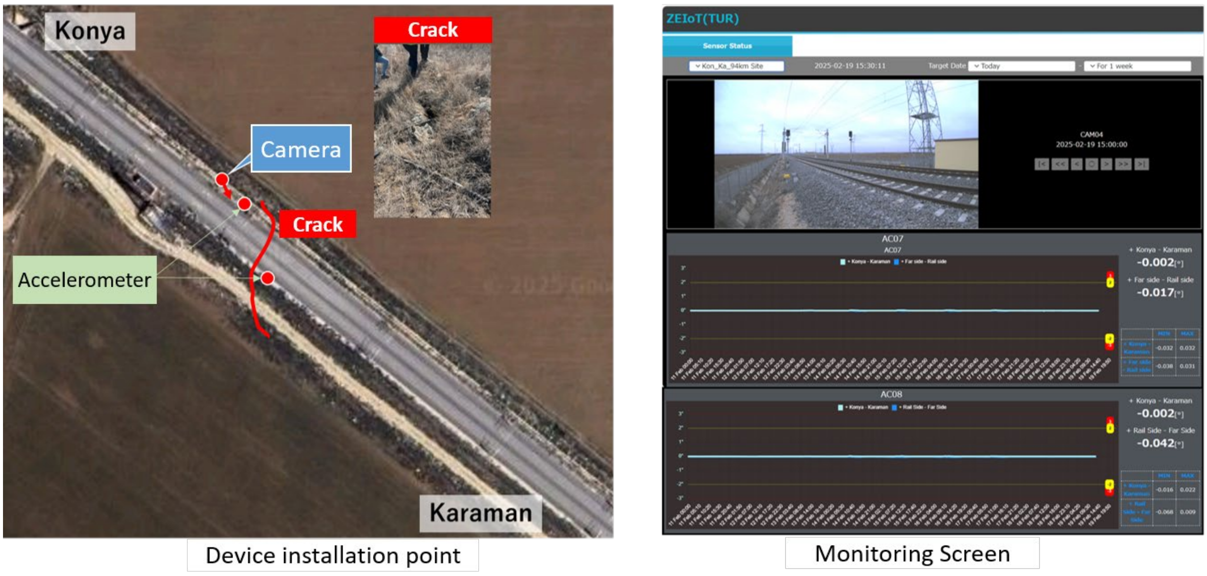
Source: JST

Figure 4-30 Figure 4-11 No.23 Earthwork 2 (Sinkhole) (Installation Status)



Source: JST

Figure 4-31 No.24 Earthwork 3 (Sinkhole) (Installation Status)



Source: JST

Figure 4-32 No.25 Earthwork 4 (Sinkhole) (Installation Status)

4.5.1 Equipment Status During the Period

The surrounding environment and radio wave conditions vary depending on the location of the device, which greatly affects the data transmission frequency and voltage drop of the device. The battery powers the accelerometer; therefore, voltage drop will be an issue during the demonstration. For devices experiencing low battery voltage, the plan is to restore power by replacing the batteries during the demonstration period. The operation of the batteries in each device is summarized in the table below.

Table 4-6 List of Status of Devices

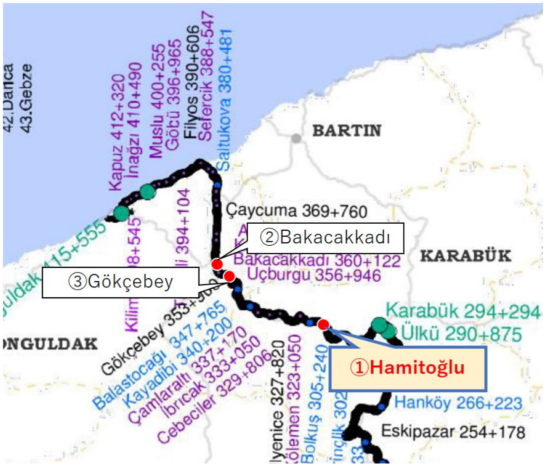
Site	Device	Battery Status
Bakacakkadi	CAM01-A	Working
	WL01-A	Working
Gokcebey	CAM02-B	Working
	AC01-B	Stopped by low battery
	AC02-B	Working
	AC03-B	Working
Tunnel Site	CAM03-SUB	Working
	AC04-B	Working
	AC06-SUB	Stopped by low battery
Kon_Ka_94km	CAM04	Working
	AC07	Working but low battery
	AC08	Working
Kon_Ka_89km	CAM05	Working
	AC09	Stopped by low battery
	AC10	Stopped by low battery
Kon_Ka_37km	AC11	Working
	AC12	Stopped by low battery
Pol_Ko_194+179	CAM06	Working
	AC14	Stopped by low battery
Pol_Ko_195+559	AC13	Stopped by low battery
Pol_Ko_184+000	CAM07	Working
	AC15	Stopped by low battery

Source: JST

4.5.2 Incident Occurred During the Period and JST's Follow-up for TCDD

At 23:40 on March 3 (local time), the accelerometer installed to detect falling rocks at No. 6 c parallel to the tracks and 6 degrees outward from the tracks. The investigation team shared the information with TCDD, and confirmed using images on the cloud that no abnormality could be seen within the viewing angle.

- Location: Karabük Hamitoğlu (see the figures below, the affected areas are in red)
- Impact on operations: None



Source: JST and TCDD

Figure 4-33 Location Map (Left) and Accelerometer Installation Pole (Right)

- JST requested TCDD to inspect the site and to understand the condition of the track, and accelerometers.
- Although rockfall was confirmed in some areas of the track, it was confirmed on-site that there was no disruption to operation (Figure: Track Condition after the detection).
- When the investigation team compared the image data taken when the fence was installed under the latest circumstances, it was confirmed that a large stone remained in the retaining wall. For this reason, it was presumed that a relatively large stone had fallen from the slope, collided with the pole or fence, and its fragments had fallen into the track. (Figure: Before (left) and after (right) the accident)
- No damage was confirmed to the accelerometer itself, and it is presumed that accelerometer can continue to be used.

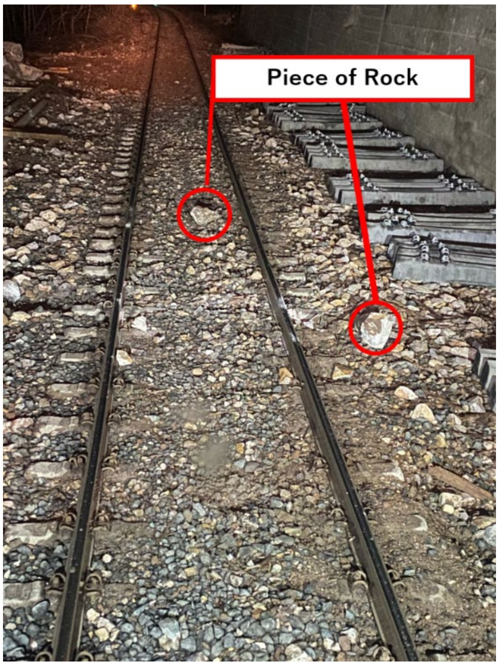
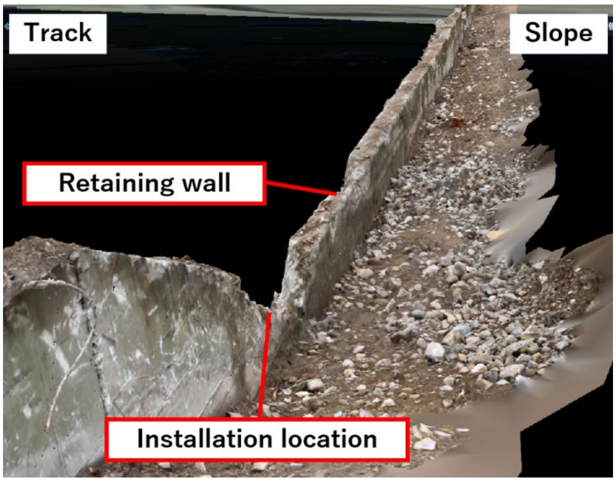


Figure 4-34 Track Condition After the Detection

Source: TCDD



Note: It can be seen that there were no rock masses present before the installation, but after the accident, relatively large rock masses had accumulated at the top of the retaining wall.

Source: JST and TCDD

Figure 4-35 Before (Left) and After (Right) the Accident

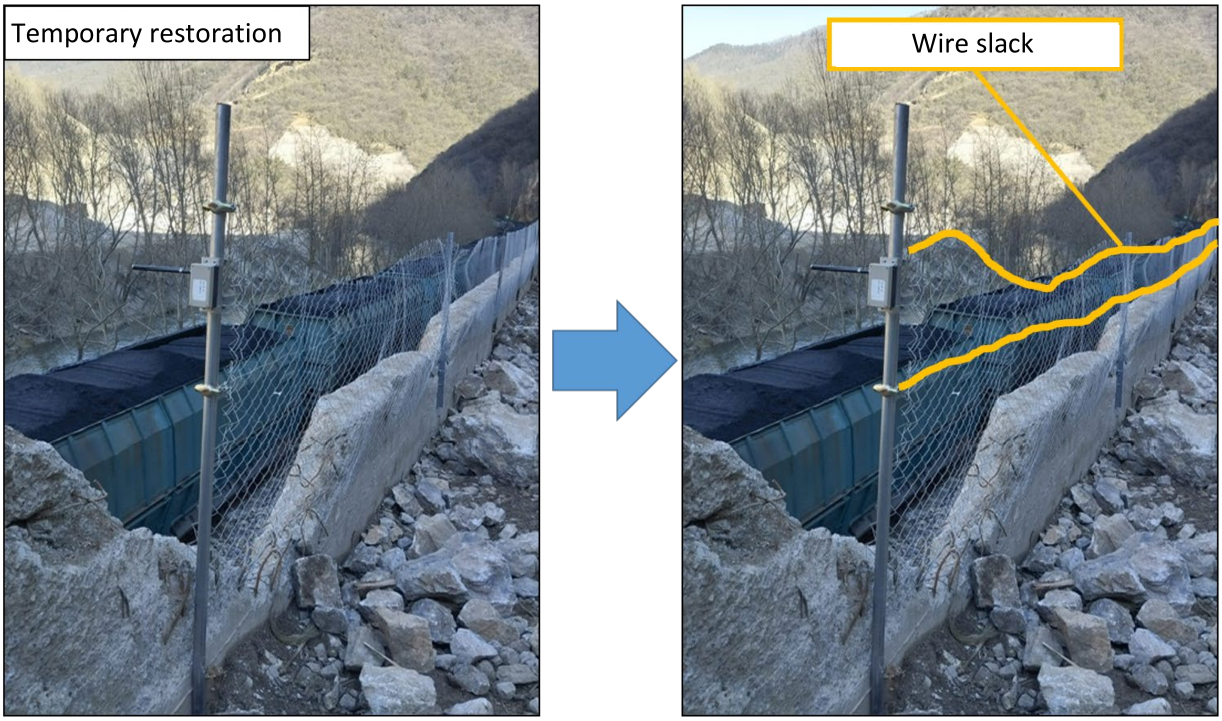
Lessons learned and improvements to be made:

- Because the email server used for distribution on the Japanese side was an Amazon service, some warning emails were blocked from being sent to TCDD. For this reason, we asked the TCDD IT team to handle the issue and ensure that emails were delivered.
- To ensure that the local maintenance office was contacted directly, we used a Google mail group and reconfigured the system so that warnings would be sent directly to maintenance staff.
- TCDD will restore and reinstall the bent pole. After the pole is restored, we will check whether the accelerometer needs to be reset.
- As no damage has been confirmed to the accelerometer, it will continue to be used at this time, but support from Japan will be needed for resetting and installing a spare unit, which may be an issue in future deployments.

Recovery status and response by JST:

- JST held discussions with TCDD on March 4th after the accident and requested TCDD to repair the movable end pole and rockfall detection net.
- After checking the restoration status through photographs (March 6, provided by TCDD) (Figure : Temporary restoration status), it was confirmed that the tension of the wires of the rockfall detection net was not appropriate.
- For this reason, an expert sent confirmation documents regarding "Notes on the construction of restoration work" and "movable end poles" and "condition of the wires," and explained the following. (See the figure below.)

- Rockfall monitoring net (wire) needs to be installed with a certain tension.
- The pole on which the accelerometer is installed supports the detection net, and since the accelerometer is the moving end that detects tilt, the detection net needs to pull the pole so that it falls.



Source: JST and TCDD

Figure 4-36 Temporary Restoration Status

4.6 Issues Identified During the On-site Demonstration Period and the Lessons Learned

(1) Lack of criteria for setting thresholds

When the measured value of the sensor equipment exceeds or falls below a preset threshold, an alert (warning email) is issued from the monitoring site, but there is no clear standard for how to set the threshold. It is desirable to accumulate measurement data in the future and create threshold setting criteria based on analysis from a technical perspective.

(2) Alert method

When issuing an alert from the monitoring site, this time it was set up to send an alert email using the e-mail system, but there was an opinion that an alert via the SMS function of mobile phones would allow infrastructure managers to grasp the situation more quickly than e-mails. In the future, we will consider the possibility of introducing alerts via SMS or other communication methods.

(3) Lack of initial response procedure and manual preparation when an abnormality is detected

In this incident, it took about five hours from detecting the abnormality to arriving at the site and understanding the situation. When actually implementing it, it will be necessary to check the site or restore operations in a short time in order to resume operations, even during the high frequency of daytime train operations. In the future, it is desirable to prepare a manual that describes the procedure from detecting an abnormality to resuming operations or carrying out restoration work, and the system that will enable this.

(4) Poor construction quality when restoring the detection device

The on-site construction supervisor did not fully understand how the detection device worked, and improper construction was carried out when the detection device was requested to be restored, resulting in a false detection. During operation, it is necessary to thoroughly educate the on-site supervisor about the mechanism of the detection device and the detailed points to be careful about when restoring the equipment.

Chapter 5 Analysis of Regulations in Türkiye Relevant to Disaster Prevention, Current Challenges, and the Future Outlook

This chapter investigates the current state of disaster prevention legislation and standards in Türkiye. It then compares Türkiye's disaster preparedness and rehabilitation assistance for railways with that of Japan and summarizes the challenges and future outlook.

5.1 Legislation related to the Disaster Management (National Level)

5.1.1 Legislation Related to Disaster Management in Türkiye

The legislation related to disaster management in Türkiye are summarized in Table 5-1.

Table 5-1 Legislation Related to Disaster Management in Türkiye

No.	Title of Law	Year	Overview
7126	Civil Defense Law	1958	This is a law on civil defense. It aims to protect lives and property from enemy attacks, natural disasters, and large-scale fires, minimizing the loss of human lives and protecting important public and private facilities.
7269	Aids to be Made with Measures to be Taken Due to Disasters Affecting Public Life (Claim Rights)	1959	The law grants the owner the right to file a claim with the State for property lost due to natural disasters. It states that victims can report damages through the "Alo 125" hotline, the e-government system, or the official website of the Natural Disaster Insurance System (DASK). As of January 1, 2023, the maximum payout for all types of buildings is TL 640,000 (33,910 USD). According to DASK, the policy covers both full and partial damage and does not require demolition of the building. Compensation will be paid once the application and required documents are completed and verified.
2935	State of Emergency Law	1983	This law provides the legal basis for the government's implementation of special measures during a state of emergency. It allows the expansion of governmental authority and partial restriction of citizens' rights under such circumstances. While it is generally applied in situations of national crisis, such as war, riots, terrorism, or civil unrest, a state of emergency was declared under this law in response to the earthquake of February 2023.
4123	The Provision of Services Related to Damages and Damages Resulting from Natural Disasters	1995	This law ensures the continuity of normal life in disaster areas and regulates the procedures and principles related to the elimination of damage and destruction and the assistance carried out by the funds established under Decree 2380
5216	Metropolitan Municipality Law	2004	This law was enacted to regulate the administrative legal status of metropolitan municipalities and to ensure that administrative services are carried out by metropolitan municipalities in an effective, efficient and harmonized manner. It regulates the responsibilities of metropolitan municipalities.
5393	Municipality Law	2005	This law regulates establishment of municipalities and

No.	Title of Law	Year	Overview
			institutions, management, duties, powers, responsibilities, operating procedures, and governance of municipalities.
5902	Establishment and duties of the Disaster and Emergency Management Presidency (Authority)	2009	This law establishes the AFAD, under the Office of the President for the purpose of effective response and governance to disasters and emergencies. It defines the duties, responsibilities, and powers of AFAD.
6306	Restructuring of areas under risk of natural disasters	2012	According to this law, the MoEUCC publishes maps of “Dangerous Areas” and “Dangerous Structures”. Building owners must report within a period of time if their properties are considered as “Dangerous Structures” in accordance with government regulations. All construction and reconstruction may be halted in high-risk areas. It also outlines procedures for government expropriation of property.
6305	Compulsory Earthquake Insurance Regulation	2012	This law establishes procedures and principles for compulsory earthquake insurance to compensate for physical damage to buildings due to earthquakes. It also provides insurance guarantees for personal and property damage resulting from disasters and risks in cases where insurance companies are imable to offer coverage.
	Regulation on Disaster and Emergency Response Services	2013	This law defines the duties and responsibilities of ministries, governorates, prefectures, and other public and private entities in emergency response. It also specifies procedures for the prompt and efficient provision of services to disaster-affected areas. It also defines principles and procedures for risk assessment and disaster response planning at national and local levels.

Source: JST

5.1.2 Türkiye's Implementation System for Disaster Risk Management

(1) Türkiye’s Disaster and Emergency Management Authority (AFAD)

In Türkiye, AFAD is responsible for disaster risk reduction. In the wake of the 1999 Marmara earthquake, the Türkiye government recognized the need for a unified disaster management agency, thus, AFAD was established in 2009 based on Law No. 5902 (Law on the Organization and Duties of the Disaster and Emergency Management Presidency) (*Currently under the Ministry of Interior). The law stipulates the establishment of both the Supreme Council for Disasters and Emergencies and the Coordination Board for Disasters and Emergencies as the national decision-making bodies related to disaster and crisis response, with AFAD as the secretariat for both authorities. The Supreme Council held twice a year, is chaired by the president, and consists of ministers of state, etc., and is responsible for approving various plans, programs, reports, etc. as the highest decision-making body in the field of disaster management..

(2) Provincial Disaster Risk Mitigation Plan (IRAP)

IRAP is formulated with the aim of reducing disaster risk in provinces based on a template created by AFAD. JICA, with AFAD as the implementing agency, conducted “The Project for Capacity Development toward Effective Disaster Risk Management in the Republic of Türkiye” from 2013 to 2017 and an integrated disaster risk assessment method for earthquakes and tsunamis was prepared. In addition, the evaluation method was used to support the creation of a regional disaster risk reduction plan for Bursa province, and the results are being utilized in the current IRAP.

The promotion of IRAP formulation is an indicator of efforts in the field of disaster management in the 11th National Development Plan (2019-2023), which has already been formulated in all 81 states of Türkiye, as of 2022. It was compiled by the State AFAD, acting as the secretariat, in collaboration with the local stakeholders, including local authorities, the private sector and academics.

Furthermore, the results of the post-project evaluation of the above project (implemented in FY2021) recommend the necessity of budgetary provision for the measures indicated in IRAP and implementation of each measure.

Compared to Japanese local government disaster management plans, IRAP devotes more space to hazard analysis. However, it treats all types of disasters equally, which means that it does not sufficiently prioritize the types of disasters according to the scale of their assumed risk. Concerning the budget, IRAP states that 1/1,000 of the municipality budget will be allocated to disaster risk reduction with distribution of specific measures to municipalities and other stakeholders. However, IRAP seems to be facing the issue of effectiveness in implementation due to the budget allocation not being legally binding on its stakeholders.

(3) Status of establishment of Diaster Affairs Deparment in municipalities

As of 2024, the establishment of a "Disaster Affairs Department" is being promoted primarily among approximately 30 metropolitan municipalities in Türkiye. These departments are organizational units within the respective municipalities and are intended to enable municipalities to independently manage disaster management without relying on AFAD. Accordingly, it is assumed that each municipality will undertake disaster response measures on its own in the event of a disaster. However, as of the time of reporting, the specific roles and responsibilities of the department have not yet been clearly defined, and the organizational structure remains unclear. Although AFAD emphasizes coordination with municipalities, it has been confirmed that no official guidelines have been currently established by AFAD regarding the formation and operational management for the Disaster Affairs Department.

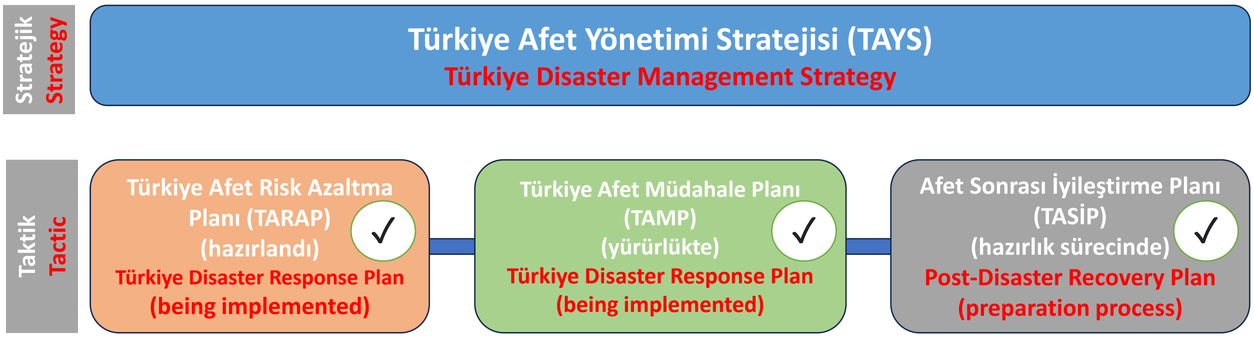
Furthermore, there is currently no direct budgetary relationship between AFAD and the municipal Disaster Affairs Departments. Unless there are changes to the existing administrative structure, these departments are expected to carry out disaster management activities through their own efforts, without receiving technical support or guidance from AFAD.

5.1.3 Policies Related to Disaster Risk Management in Türkiye

Türkiye's national-level disaster risk management and reduction plans are formulated by AFAD, based on the National Development Plan. The 11th National Development Plan (2019–2023) emphasizes the promotion of disaster risk reduction through mitigation initiatives that aim to enhance public understanding of disasters, build a disaster-resilient society, and minimize the loss of lives and property. The national disaster management framework consists of three main plans: TARAP (Türkiye Disaster Risk Reduction Plan), TAMP (Türkiye Disaster Response Plan), and TASIP (Türkiye Disaster Recovery

Plan). These plans are developed under the guidance of the TAYS (Türkiye Disaster Management Strategy Document), and together they provide strategic direction for disaster management before, during, and after disasters, respectively.

TARAP and TAMP have already been formulated and are currently in force, while TASIP was officially announced in January 2023 (Figure 5-1).



Source: Remade by JICA Expert Team based on the information on AFAD website

Figure 5-1 National Disaster Management Planning and Formulation Situation in Türkiye

(1) Türkiye Disaster Management Strategy Document and Action Plan (TAYS)

TAYS represents a vision of the Türkiye national disaster management system that, encompasses existing and emerging disaster risks, all disasters and emergencies, and all processes of disaster management. TAYS describes effective disaster management practices, including the effective use of resources. Public institutions, organizations, academic institutions, the private sector, NGOs, media, and individual citizens to international organizations are listed as stakeholders in disaster management. The enforcement of TAYS was decided at the Disaster and Emergency High Council in December 2017.

(2) Türkiye Disaster Risk Reduction Plan (TARAP)

TARAP is AFAD's national plan for the period 2022-2030, which aims to minimize disaster risk. TARAP seeks to prevent or minimize physical, social, economic, environmental, and psychological damage and loss caused by disasters. TARAP also aims to create a sustainable and disaster resilient living environment and to establish basic principles that should be prepared for and implemented before a disaster strikes.

The priorities defined in the Sendai Framework for Disaster Reduction (2015-2030) are incorporated into the priorities of the TARAP, and the content of the priorities for each strategy defines goals, objectives, actions, responsible organizations, and subsidiary responsible agencies. Specific measures are implemented under short term (2022-2024), medium term (2022-2028), and long term (2022-2030) plans. TARAP includes 17 goals, 66 targets, and 227 action plans related to 11 different types of disasters published after presidential approval on July 8, 2022.

(3) Türkiye Disaster Response Plan (TAMP)

The purpose of TAMP is to clarify the roles and responsibilities of ministries, agencies and organizations, the private sector, and NGOs participating in response activities related to disasters and emergencies, and to establish basic principles for response planning before, during, and after a disaster occurs. The first edition was published in 2014, and the latest edition entered into force in 2022 with strategies based on past disasters that have occurred in Türkiye.

TAMP includes 25 disaster groups at the national level and 23 groups at the local level, with the Presidential Department of Public Information, Ministry of Interior, Ministry of Family and Social Services, MoEUCC, Ministry of Energy and Natural Resources, MoF, MoH, Ministry of Agriculture, Forestry and Fisheries, Ministry of Transport and Infrastructure, and General Directorate of the Red Cross Society of Türkiye as key responsible institutions. The other ministries, institutions, and organizations are positioned as auxiliary subsidiary bodies.

(4) Türkiye Post Disaster Recovery Plan (TASIP)

The Türkiye Disaster Recovery Plan (TASİP) is a plan developed by AFAD to effectively and rapidly advance the process of disaster recovery. Officially announced in January 2023, the main objective of the Plan is to implement post-disaster recovery activities in a more systematic and cooperative manner, with steps ensuring the safe return of people to pre-disaster routines as quickly as possible.

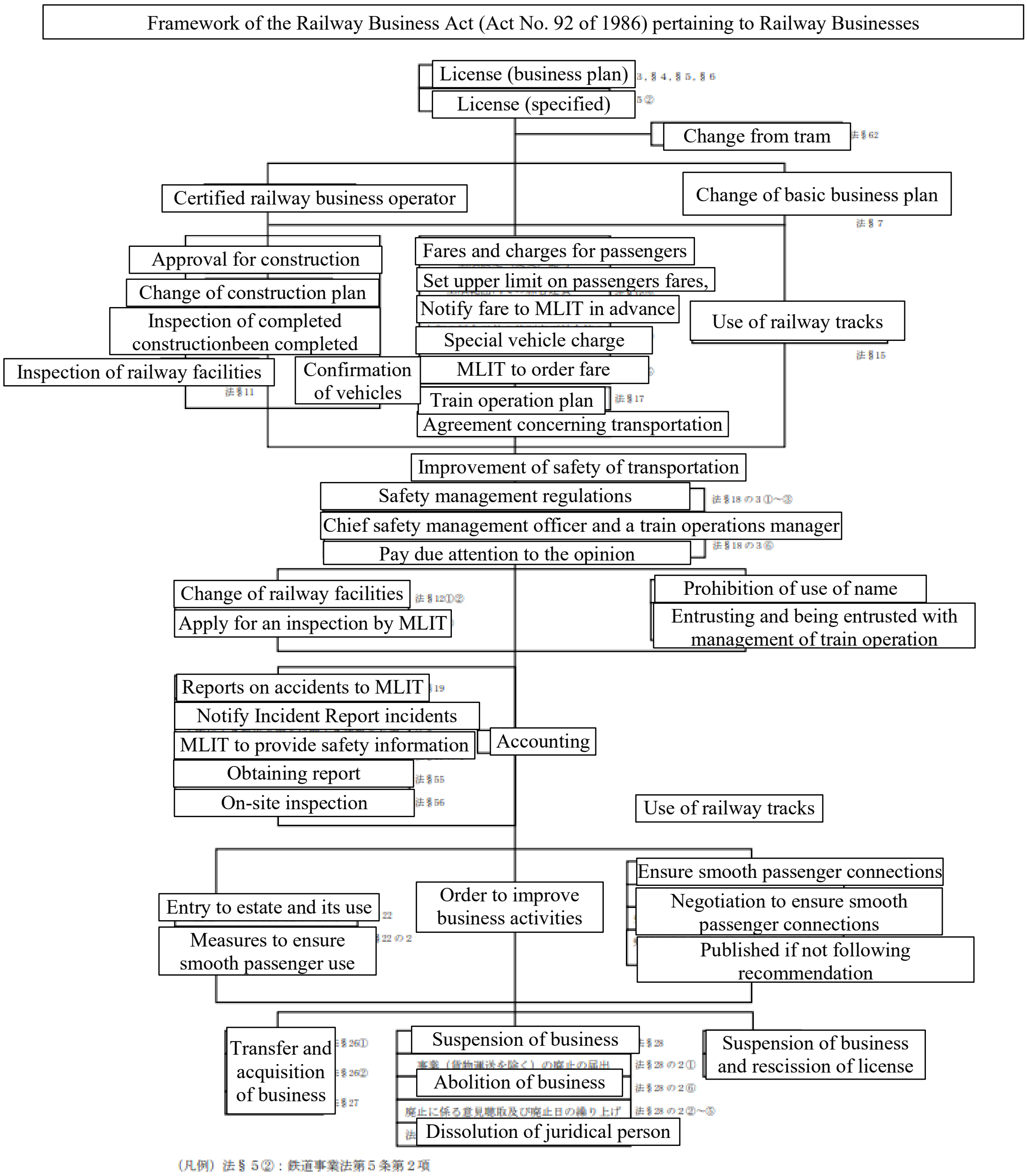
5.2 Survey of Japanese Railway Disaster Prevention Legislation and Standards

5.2.1 Railway Technical Standards in Japan

(1) Railway Operation in Japan

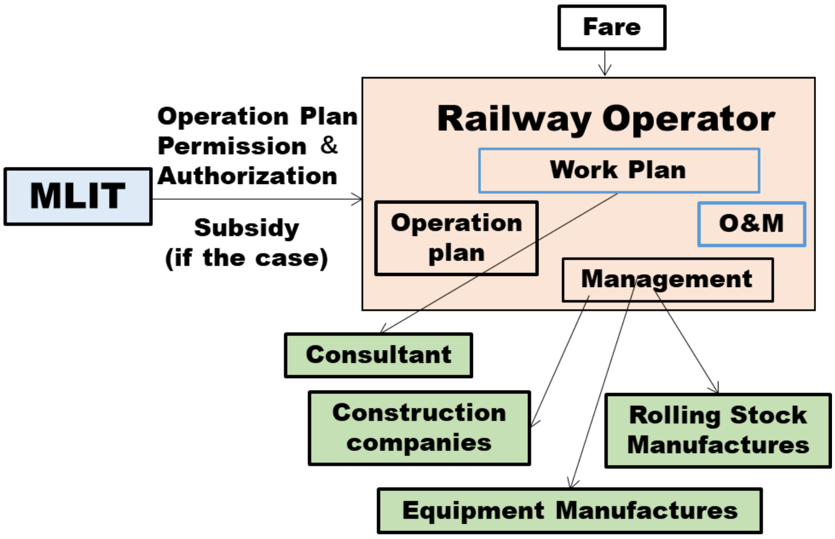
Figure 5-2 illustrates the system of Japan's Railway Business Law, while Figure 5-3 outlines the concept framework of railway operation by the railway operator. The railway operators have licenses from the Ministry of Land, Infrastructure, Transport and Tourism. Each licensed operator formulates and implements detailed work plans, operates the railway and directs manufacturers, construction companies and others. The railway operator is legally responsible for all aspects of the railway, from construction to operation, and its ability to carry out these tasks on its own is a condition of its business license.

Given this background, railway operators in Japan have developed their own technical systems while complying with laws and regulations. However, this has led to a lack of standard practices and insufficient development of common standards for the railway industry.



From MLIT railway bureau

Figure 5-2 Railway Business Act and Related Acts



Source: Kazuhiro Tanaka, 'Overseas railway operations and business potential', JREA Magazine, Jan 2017 (in Japanese).

Figure 5-3 Relationship Around Railway Operator in Japan

(2) Technical Standard on Railways in Japan

The Technical Regulatory Standards on Japanese Railways are so-called performance regulations that stipulate the performance that railway facilities must have to ensure safe and stable railway operation. In addition to these, the Ministerial Ordinances and other interpretations are explained in a non-binding manner in the Interpretation Standards and Explanation. It determines specific, numerical values and clarifies the decision-making criteria. These serve as reference for technical decisions to guide railway operators, and in examinations for licensing and approval by the Ministry of Land, Infrastructure, Transport and Tourism.

While applying the Ministerial Ordinance and the Interpretative Standards and the Explanation, railway operators establish detailed internal standards called 'Standards of Implementation', which reflect individual circumstances and are used to design, operate, handle and maintain facilities and rolling stock in accordance with the standards.

Overall, the performance and operational methods to be provided by railway facilities are stipulated in ministerial ordinances, interpretation standards and implementation standards. While the actual railway facilities are designed, constructed and operated on the basis of these regulations as well as JIS (Japanese Industry Standards) and other national standards. The system of applicable technical standards is shown in Figure 5-4.

1) Technical Regulatory Standards on Japanese Railways

i. Technical standards for railways

The Ministerial Ordinance on the Technical Regulatory Standards on Japanese Railways (hereinafter referred to as the 'Technical Standards') was promulgated in 2001 and came into force in 2002. It is based on the provisions of Article 1 of the Railway Operation Act, with subsequent revisions, and consists of the following 11 chapters. Chapter 1 General Rule; Chapter 2 Staff; Chapter 3 Guide Way;

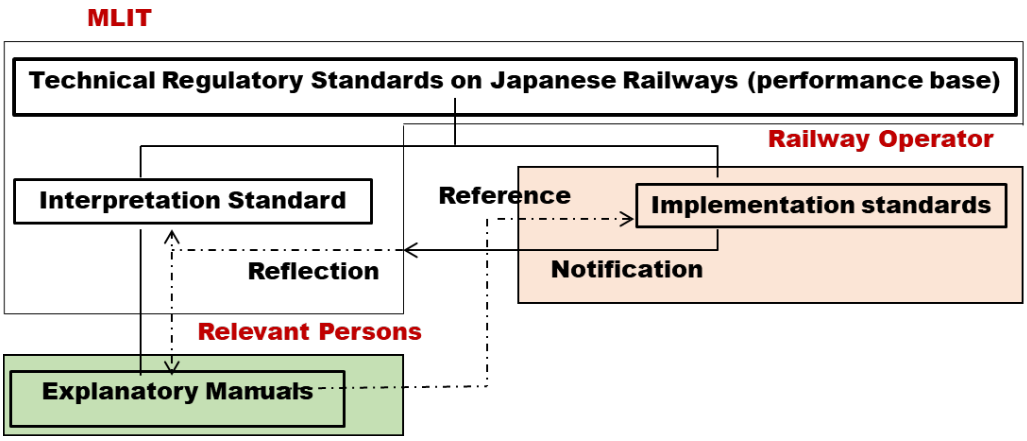
Chapter 4 Station and Halt; Chapter 5 Intersection with Road; Chapter 6 Electrical Facilities; Chapter 7 Operation Safety Facilities; Chapter 8 Rolling Stock; Chapter 8-2 Other Facilities; Chapter 9 Maintenance of Facilities and Rolling Stock; Chapter 10 Train Operation; Chapter 11 Special Railways. In order to increase the technical freedom of railway operators and to allow for the introduction of new technologies and a flexible response to the individual circumstances on railway lines, etc., the 'performance regulations' do not prescribe individual figures and specifications, but rather provide systematic performance requirements as far as possible.

ii. Interpretation of standards

The interpretation of standards for "Technical Standards" is notified by the Director-General of the Railway Bureau (of MLIT) to provide a reference for technical decisions by railway operators when operating performance regulations, and to clarify the criteria for decision-making when the Ministry of Land, Infrastructure and Transport examines licensing and approval, etc., by specifying and quantifying the interpretation of ministerial orders and other regulations.

iii. Explanation

An explanation is a summary of the rationale and approach for setting ministerial orders and interpretative standards, where necessary, for the reference of operators, and the Technical Standards on Railways fall into this category. The relationship between them is shown in Figure 5-4.



Source: MLIT Railway Bureau

Figure 5-4 System of Technical Regulatory Standards for Railway (MLIT)

2) Standards in Railway Operators

i. Implementation standards

Within the framework of the Ministerial Ordinances and related regulations, railway operators shall formulate detailed 'Standards of Implementation' reflecting actual conditions. Operators shall refer to the interpretation standards or commentaries, for the design facilities and vehicles, and operation and handling..

When formulating or amending the "Implementation Standards", the railway operators shall notify the Ministry of Land, Infrastructure, Transport and Tourism of the contents of the "Implementation

Standards" in advance, in order to confirm the contents of the "Implementation Standards" that are not included in the "Interpretation Standards" and to promptly reflect them in the Interpretation Standards, thereby ensuring their wide dissemination and making individual procedures and subsequent checks more efficient and speedy.

ii. Design and construction standard

This standard provides specifications and construction methods that conform to the 'Implementation standards' established by the railway operators. It defines the functions, performance requirements, standard design, design calculation methods, testing methods and other details of railway facilities, for routine designs and maintenance work. The former Japanese National Railways established various design and construction standards for railway facilities, such as tunnels and viaducts. Even today, each railway operator has its own design and construction standards or equivalent standards, but these are not, in principle, made public.

5.2.2 Sharing of Restoration Costs in the Case of a Disaster in Japan

(1) Principle: Railway Operators Bear the Whole Costs

On Japanese railways, railway facility owners are responsible for the maintenance and operation of their facilities in accordance with the above-mentioned regulations. In principle, therefore, railway operators bear the costs of restoration and recovery work in the event of natural disasters such as earthquakes, heavy rain, strong winds and heavy snowfall, as well as disaster prevention and mitigation measures.

(2) The Measures for Disaster Prevention and Mitigation of Disasters on Railways

In October 2018, in view of the increasing and severe damage to railway facilities caused by the recent spate of natural disasters, MLIT issued 'Measures for Railway Disaster Prevention and Mitigation'. These measures are for railway disaster prevention and mitigation from the user's perspective, including early restoration of railway facilities.

The Measures for Disaster Prevention and Mitigation of Disasters on Railways provides an overview of the progress of disaster prevention measures taken by railway operators and the Government to date and the recent disaster situation, and sets out the following measures in Table 5-2.

Table 5-2 Disaster Prevention and Mitigation Measures for Railways

	Earthquake	Heavy Rain
Disaster prevention (structural measures)	Steady promotion of seismic reinforcement, in addition to existing reinforcement targets and study of new reinforcement targets.	Study of support measures from MLIT to promote the prevention of railway river bridges from being demolished, etc.; Flood prevention measures for critical facilities such as power supply equipment, etc.
	Study on measures to prevent the inflow of sediment from outside the railway operator's site.	
Disaster	Establish a mechanism for early restoration through cooperation and coordination with related	

	Earthquake	Heavy Rain
recovery (structural measures)	projects; Establish a mechanism for early restoration and prevention of recurrence of slope failures, including in adjacent areas. Study on how to build consensus among relevant parties for railway restoration, etc.	
Disaster response measures (non-structural measures)	Regularly survey and monitor the progress of measures for people who have difficulty returning home, and provide guidance from MLIT to railway operators on necessary improvements. Study on strengthening the provision of information to passengers, especially inbound passengers, immediately after a disaster.	
	Coordination with relevant parties for measures to prevent long-term closure of level crossings.	

Source: MLIT

Based on this government policy, subsidies for the cost of comprehensive safety measures for railway facilities have been launched and are in operation.

- Countermeasures against floods in railway

Objectives and project overview

Objective:

To promote flood prevention measures at underground stations entrances and exits, tunnel openings, and similar locations., vulnerable to serious flood damage in the event of a river flooding or a tsunami, further preventing flood damage before it occurs and to limit its spreading.

Overview:

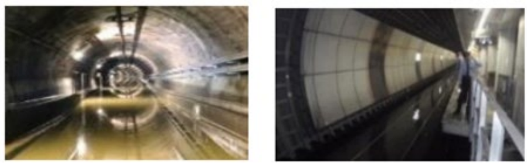
MLIT supports the construction of watertight panels and watertight doors at entrances, exits and tunnels of underground stations where flooding damage is anticipated according to hazard maps and other information provided by local authorities. In addition, based on the recent trend of heavy rainfall disasters, MLIT will also provide support for new flooding countermeasures for electrical equipment, etc.

Scheme Details

Support for Railway Undertakings: Railway undertakings. (excluding JR East, Central and West Japan)

Facilities to be Subsidized: Installation or relocation of watertight panels, waterproof doors, flood prevention equipment, etc. at station entrances and exits, tunnel entrances, ventilation openings, electrical equipment, etc.

Subsidy rate: within 1/3 (Local governments provide



The images of flooding in underground stations.
(Left: Typhoon affected Kyoto Metro in September 2013. 4 days stoppage, 450 thousand people affected)
(Right: Typhoon affected Odakyu Railway in October 2013. 3 hours stoppage, 410 thousand people affected)

The images of Measures against floodings
(Upper left: Doors to prevent floods)
(Upper right: Electric facilities to be lifted up)
(Lower left and right: Water stop boards and doors on entrances)

coordinated assistance). 85% of (150 bridges, 1200 slopes, 510 Metro entrances, and 190 electrical facilities) shall be reinforced from 2020 to2025.	

Source: MLIT Railway Bureau

Figure 5-5 Countermeasures Against Floods in Railway

- Protection against for Heavy Rains

Object: In view of the increasingly severe and frequent heavy rainfall disasters, measures to prevent the damage of railway bridges from rivers and the inflow of sediment from slopes adjacent to railways are promoted to ensure the safety of railway users and maintain a safe, stable railway operations.

Overview: MLIT supports measures to prevent scouring of piers, bridge replacement, and reinforcement of slopes that are adjacent to railways and other measures against heavy rainfall, specifically prioritizing railway sections with a large number of users.

Subsidized Operators: Railways operators (excluding JR East, Central and West Japan).

Projects eligible for assistance: Reinforcement of piers (scour prevention measures),
Maintenance of abnormality detection systems,
Bridge replacement, reinforcement of slopes adjacent to railways, etc.

Subsidy Rate: Within 1/3 of the reinforcement cost

Project category	Target line area	Target project
Railway River Bridge Improvement Projects	Routes with one-way sectional traffic, and has more than 10,000 but less than 150,000 passengers per day	Reinforcement of bridge pier foundations Installation of an abnormality detection system Bridge replacement
	Lines where express trains or freight trains operate.	
Rail Slope Improvement Projects	Routes with one-way sectional traffic, and has more than 10,000 but less than 150,000 passengers per day	Slope protection works Rock fall protection works
	Lines where express trains or freight trains operate.	

Measures against heavy rains

(From left: JR West Kure line in 2018 with inflow of sediment, and reinforced slope with concrete frames)

(Right: Reinforced bridge piers with concrete blocks)

Source: MLIT Railway Bureau

Figure 5-6 Protection Against for Heavy Rain

- Earthquake Preparedness of Railways

In Japan, of the total natural disaster damage to railway facilities during 2010-20, earthquakes occupy 17% and heavy rains 79% (other damages were caused by big waves, strong winds, lightning strikes,

etc.).
Earthquake resistance measures are based on ministerial ordinances and are a long-term effort.
As of 2018, 97% of viaducts and 94% of station buildings have been reinforced. 1/3 of the reinforcement cost is subsidized (exception, JR East, JR Central, and JR West)
EEW (Early Earthquake Warning) system for high-speed rail: Mutual use of railway-owned seismographs and JMA (Japan Meteorological Agency) owned seismographs.
Derailment prevention for high-speed rail: Promote the development of derailment and deviation prevention devices.
Seismic reinforcement of structures for high-speed rail: Early implementation (by 2025) of reinforcement of viaduct (120,000 pillars), accelerated reinforcement (by 2027) of catenary poles (25,000 poles).
Objective: In preparation for large-scale earthquakes such as an earthquake directly under the Tokyo capital or a Nankai Trough Earthquake, MLIT promotes seismic measures at main stations and viaducts, etc., to ensure the safety of railway passengers.
Overview: MLIT supports seismic measures at stations and elevated bridges in areas where a Japanese seismic intensity of 6 or higher is expected in the event of an earthquake that is directly under the Tokyo capital or a Nankai Trough Earthquake, targeting railway lines with a large number of passengers.
Subsidized Operators: Railways operators (excluding JR East, JR Central and JR West).
Projects Eligible for Subsidy: Seismic reinforcement of stations, elevated bridges, etc.;, implementation of measures to prevent bridges from falling, etc.
Subsidy Rate: Within 1/3 of the reinforcement cost

Objective	Target area	Target line/station	Target facility
Reinforcement to ensure that structures do not collapse (shear failure leading) in the event of a major earthquake.	Areas with a seismic intensity of 6 or higher in the event of an earthquake directly under the Tokyo capital or a Nankai Trough earthquake, etc.	Line sections with a one-way cross-sectional transport capacity of 10,000 passengers per day or more (e.g. line sections with 10 trains per hour or more each way).	Viaducts Bridges (including those with locking piers) Tunnels
	Nationwide	Line sections that intersect or run parallel to emergency transport roads, etc.	
		Stations with more than 10,000 passengers per day.	Overbridges, etc.
Reinforcement with the aim of minimizing deformation (bending fracture ahead) from the viewpoint of early restoration.	Areas where seismic intensity is expected to exceed 6 on the Japanese seismic intensity scale in the event of an earthquake directly under the capital or a Nankai Trough earthquake, etc.	Line sections with one-way cross-sectional traffic of 50,000 passengers or more per day.	Viaducts

Reinforced Viaduct Pillars
Photos: MLIT

Source: MLIT Railway Bureau

Figure 5-7 Earthquake Preparedness of Railways

➢ Measures for Ageing Railway Facilities

Object: To promote appropriate maintenance and renewal of ageing railway bridges and tunnels, ensuring the safety of railway users and, maintain a safe, stable railway operations.

Overview: Targeting railway operators in rural areas where the local population is declining and the business environment is becoming increasingly severe, MLIT supports the improvement and repair of railway facilities that contribute to reducing future maintenance and management costs, and extends the service life of railways, after confirming the continuity of railway business, etc.

Subsidized Operators: railway operators (Excluding JR East, JR Central, JR West, JR Freight, major private railways, semi-major private railways and local public bodies (Type 1 and 2 railway operators)).

Projects eligible for subsidy: Anti-corrosion coating of bridges, reinforcing concrete lining of tunnels, etc.

Subsidy Rate: Within 1/3 of the reinforcement cost

Measures against ageing facilities

(Left: Anti-corrosion coating to bridges, Right: Fiber-sheet reinforcement to tunnels)

Source: MLIT Railway Bureau

Figure 5-8 Measures for Ageing Railway Facilities

In addition to the measures mentioned above, specific early restoration initiatives are listed below.

➢ Assistance for Disaster Rehabilitation of Railway Facilities

Objective: To support the early restoration of railways that were damaged by earthquakes, torrential rains and other disasters.

<table>
<tr><td>Subsidies for Disaster Restoration of Railway Facilities under the Railway Track Improvement Act.</td><td>Subsidies for Disaster Recovery of Railway Facilities in Specific Large-scale Disasters, etc.</td></tr>
<tr><td>[Deficit routes of loss-making operators]
Target disaster: Major disasters caused by floods, earthquakes and other unusual natural phenomena
Subsidy requirements: Must fall into one of the categories below.
The operator that is affected by the disaster must have been in the red for the past three years or is expected to be in the red for the next five years or more.
The cost of restoration must be at least 10% of the route's annual transport income.

[Deficit lines* of profitable operators (e.g. JR Hou-hi Line)]
Targeted Disasters: Severe disasters and other similar disasters of a particularly large scale.
Subsidy Requirements: All of the below must be met.
The route that is affected by the disaster has been in the red for the past three years.
The cost of restoration is more than the annual transport income of the route.
The operator must prepare a plan to ensure long-term operation.</td><td>**Eligible disasters:** Disasters specified in Article 2(9) of the Act on Recovery from Large-Scale Disasters or Article 2(1) of the Act on Special Measures for the Preservation of the Rights and Interests of Victims of Specified Emergency Disasters.
Subsidy requirements:
The operator affected by the disaster has been in the red for the past three years or is expected to be in the red for the next five years or more.
The cost of restoration is more than the annual revenue of the route.
The operator must have a plan to ensure the long-term operation of the line.
A public entity has possession of railway facilities that are restored by railway operators due to changes in business structure.
Subsidy Rates:<table><tr><td>Entity</td><td>Government</td><td>Railway Operator</td></tr><tr><td>Share</td><td>50%</td><td>50%</td></tr></table>100% of the bonds are allocated to subsidized disaster recovery projects, and 95% of the principal and interest</td></tr>
</table>

Subsidy rates:

Entity	Government	Local Gov.	Railway Op.
Share	25%	25%	50%

Increase in subsidy rate*: 25% to 33% (JR Tadami Line)

Requirements: All of the criteria below must be applicable.

Difficulty in securing public transport to replace railways that are damaged by disasters.

A public entity owns the restored railway facilities due to a change in the business structure.

*Addition due to revision of law in June 2018

(JR Tadami Line restored after heavy rain in July 2011)

repayments are subject to ordinary taxation.

Examples:

<u>Minami Aso Railway, Sanriku Railway, Ueda Dentetsu, and Kumagawa Rail</u>

(Minami-Aso Railway, damaged by earthquake in April 2016)

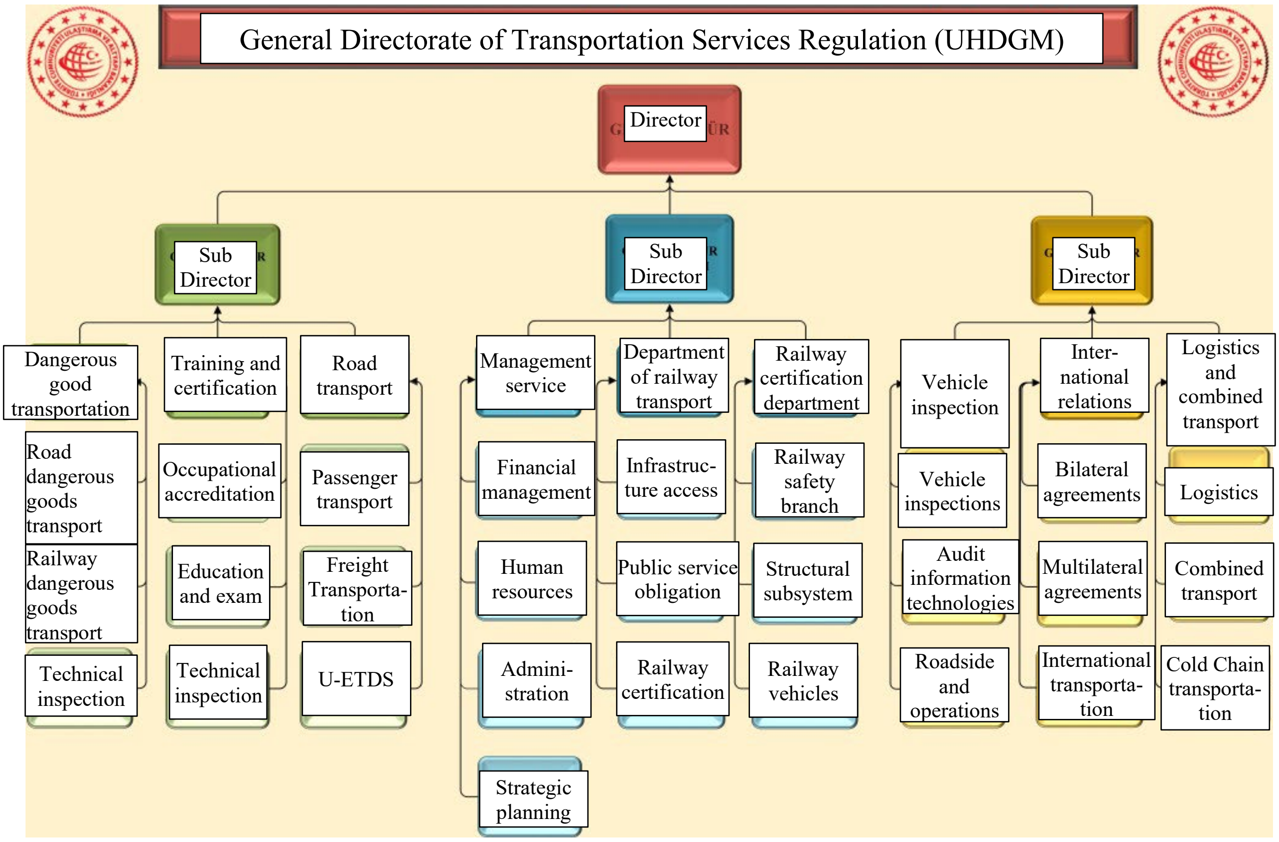
Source: MLIT Railway Bureau

Figure 5-9 Subsidy Scheme for Disaster Restoration of Railway Facilities

5.3 Survey of Turkish Railway Disaster Prevention Legislation and Standards

5.3.1 UHDGM (Ulaştırma Hizmetleri Düzenleme Genel Müdürlüğü, General Directorate of Transportation Services Regulation)

Within the Turkish Ministry of Transport and Infrastructure, the Directorate General for Service Regulation UHDGM (Ulaştırma Hizmetleri Düzenleme Genel Müdürlüğü) is responsible for land transport, i.e. rail and motor transport (organizational chart shown in Figure 5-10). Within UHDGM, the Department of Railway Transport oversees railway operations, while the Railway Certification Department has jurisdiction over technical matters.



Source: UHDGM website

Figure 5-10 Organizational Structure of UHDGM

(1) The Duties and Powers of the Department of Railway Transport (Website of UHDGM)

a) To issue authorization certificates of those engaged in these activities in accordance with the principles of financial competence, professional competence and professional prestige for railway infrastructure operators, railway train operators, depot or station operators and similar transportation activities on the railway, and to carry out the work and transactions related to the renewal or cancellation of the authorization certificates issued.

b) To carry out conformity assessment and control activities within the framework of the authorization criteria of the institutions/organizations to which the authorization certificate has been issued.

c) To follow the work carried out within the International Railway Transport Intergovernmental Organization (OTIF) and the European Railway Agency (ERA), to ensure coordination and to carry out the work and transactions related to the meetings in this regard.

d) To closely follow the work of the EU Progress Report, to evaluate the issues related to the railway sector, to inform the relevant units, to ensure coordination, to form opinions and to prepare correspondence when necessary.

e) To closely follow the studies on the railway sector within the scope of the European Commission Sub-Committee meetings, to carry out the work and transactions related to the meetings on this subject, and to ensure coordination.

f) Within the framework of Türkiye-EU financial cooperation, to develop project proposals for the railway sector, to prepare the project technical receipt and technical specifications, to carry out the work and transactions for the implementation and coordination of the projects.

g) To regulate and supervise competition among railway infrastructure and train operators engaged in railway transportation activities in a free, fair, sustainable and non-monopolistic manner.

h) To make arrangements regarding the use, allocation, access and pricing of railway infrastructure, and to carry out and supervise the work and transactions related thereto.

i) To determine and supervise, when nesessary, the implementation of base and ceiling fees for railway infrastructure usage fees and transportation activities.

j) To make decisions for the resolution of disputes between the railway infrastructure operator and the railway train operators regarding the use, allocation, access and pricing of railway infrastructure.

k) To make impact analyses of the infrastructure access fee to be determined by the railway infrastructure operator for the railway transportation market and to take the necessary measures according to the results.

l) To evaluate the capacity allocation, usage charging contracts and traffic performance made by the railway infrastructure operator, and to take measures by making necessary opinions and suggestions.

m) To determine the rights, obligations and responsibilities of the railway infrastructure operator, railway train operator and passengers traveling on the railway, which produce services in the field of railway transportation.

n) To determine the procedures and principles regarding the public service obligation in railway passenger transportation, to prepare and execute public service contracts, to peform tasks and transactions related to the procurement of the service, and to inspect its compliance with the contracts.

(2) The Duties of the Railway Certification Department (Website of UDHGM)

a) To increase the safety performance of railway infrastructure and train operators in railway transportation, to prepare regulations, common safety methods and indicators for the establishment of the safety management system of the said operators, and to carry out conformity assessment and control activities.

b) To create RAMS plans in coordination with system engineering studies and to organize and carry out activities to increase operational efficiency.

c) To issue safety authorizations of railway infrastructure operators and safety certificates of railway train operators.

d) To prepare the annual report based on the annual safety reports of railway train operators and railway infrastructure operators for the previous calendar year, which includes activities related to railway safety.

e) To examine the reports of accidents and/or incidents prepared by the relevant institutions and sent to the General Directorate, to make necessary opinions and suggestions, and to evaluate this issue in coordination with the relevant institutions.

f) To carry out inspection activities in terms of safety procedures within the framework of relevant legislation for railway train operators and railway infrastructure operators who have safety certificates and safety authorizations.

g) To determine the professional competence conditions of the personnel who will perform safety-critical duties in the railway sector, especially train drivers, railway infrastructure operators and railway train operators, in coordination with the relevant institutions and organizations, to provide or have training given in this regard, to conduct or have exams conducted, and to authorize them and to carry out inspection activities.

h) To issue a Train Driver's License to train drivers on behalf of MOT.

i) To carry out joint studies with the relevant institutions/organizations on the determination of the curriculum/curricula of the organizations that will provide compulsory vocational training for the personnel who will work in safety-critical tasks in the railway sector.

j) Within the framework of the technical requirements for interoperability and other applicable international standards in accordance with EU legislation; To determine the standards of all kinds of towing and towing railway vehicles to be produced domestically or imported / leased from abroad (new or old) and to be used in the national railway infrastructure network, to give type approval according to these standards and to determine the procedures and principles regarding their registration, and to keep records.

k) To authorize the notified body, appointed body, independent risk assessment body and UTP assessment bodies that will carry out the control, testing and inspection works to ensure that the design and manufacture of all kinds of towing and towing railway vehicles to be used in the national railway infrastructure network comply with the relevant standards and to determine the procedures and principles regarding these issues.

l) To define the minimum qualifications of those who will carry out the maintenance, repair and, if any, periodic technical inspections of all kinds of towing and towing railway vehicles to be used in the national railway infrastructure network, and to authorize and supervise them and to determine the procedures and principles regarding these issues.

m) To determine the procedures and principles regarding the inspections of railway above-ground subsystems (infrastructure, automation, signaling and electrification), to implement them, and to certify them in accordance with the standards.

n) To determine the minimum qualifications of those who will carry out inspections of railway above-ground subsystems (infrastructure, automation, signaling and electrification), and to authorize and inspect them in accordance with the standards.

o) To ensure that the performance is increased by determining the appropriate standards for the signaling, automation system and electrification system.

p) To evaluate the RAMS documents created for the signaling system in the light of technological developments and to realize appropriate strategies to increase performance.

q) To realize strategies that support locality within the scope of urban railway projects, to carry out some work activities in the plan to be created in this context.

r) To prepare and have prepared regulations regarding urban railways.

s) To follow the technological developments in the activities carried out in relation to the urban railway and to ensure that the relevant changes are added to the system as added value.

t) To prepare regulations regarding the lines of contact and to ensure the necessary coordination among the stakeholders.

(3) The Result of Interviews With UHDGM

A meeting was held with Ms. Mert (Deputy Director of UHDGM) on June 27, 2024 to discuss UHDGM’s mission and disaster response measures.

a.) The current scope of the UHDGM is to establish technical standards and regulations for the construction and operation of TCDD; UHDGM will be studying the technical management of urban railways such as Ankara Metro and Metro Istanbul in the near future and would like to develop legislation and bring it up to regulation (ACT). In any case, UHDGM’s task is to develop technical standards based on the law.

b.) Deputy Director Mert has worked in Metro Istanbul and is familiar with railway practices.

c.) There were many inconsistencies with TCDD operations when separating TCDD into upper and lower levels and applying the European TSI; since the appointment of Deputy Director Mert in 2020, domestic standards applicable to Turkish domestic railways have been developed due to the small ratio of international TCDD operations, reducing the obstacles to actual railway operations.

d.) Japan's concept of a railway with integrated upper and lower management is instructive. In response to Japan's current situation of early warning systems and proactive response to natural disasters, the Turkish government would like to respond positively by including the introduction of early warning systems in the technical standards in Türkiye.

e.) Technical standards for urban railways are set by each Turkish local municipality. For example, Ankara Metro has no flood protection measures as the region has low rainfall. Metro Istanbul has developed safety standards during Mert’s time as Deputy Director, and as a result, it is safe even in case of flooding. In any case, local municipalities alone are limited in their safety measures for urban railways.

f.) Deputy Director Mert was reluctant to establish a data partnership between other ministries such as

AFAD/MGM and UHDGM; Deputy Director Mert was of the opinion that it is not easy to use other ministries' data in Türkiye and that TCDD should first develop the necessary sensors etc. by itself.

g.) In Japan, railways are deeply rooted in society and railway operators enjoy the trust of society. The railway operators are making a profit and are voluntarily promoting various safety measures with the idea of protecting customers from danger. He explained that the railway operators' response to congestion is also mainly based on responding to customer complaints.

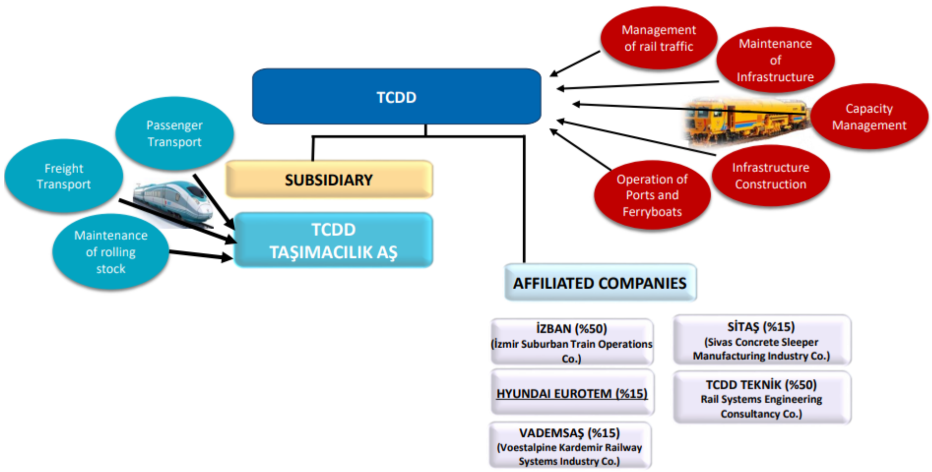
h.) In the case of Türkiye, the railways do not make a profit. Therefore, he was of the view that new safety measures would not be disseminated to railway operators unless technical standards were developed in accordance with the law.

5.3.2 TCDD

(1) Vertical Separated Structure of TCDD and TCDD Transport

In 2017, Turkish State Railway TCDD was reorganized into the state-owned infrastructure management company TCDD, which owns the overall facilities, and TCDD Transport, the passenger and freight operator, resulting in the so-called vertically separate upper and lower railway operating structure of TCDD Turkish Railways as the same corporate group.

Within the framework of TCDD's investment plan, the Turkish Ministry of Transport and Infrastructure and state officials are rehabilitating existing railway lines, bringing rolling stocks up to international standards (mostly EN), improving reliability and providing international-standard training for TCDD's technical staff.



Source: TCDD

Figure 5-11 Structure of TCDD After 2017

This separation of infrastructures and operators of railway operations, i.e. vertical separation, was initiated in Europe in 1991 as a means of introducing competition among railway operators. Subsequently, railways in Asia and other parts of the world have also adopted the vertical separation system. The EU Directive 91/440/EEC of the same year stipulated the 'separation of accounting for the infrastructure and transport sectors', and the First Railway Package under 2001/14/EC in 2001 transferred responsibility for setting timetables from the passenger and freight operators (i.e. top down) to the infrastructure managers (i.e. bottom up), as a measure to promote competition between railway operators.

In Germany, France, South Korea and other countries, the infrastructure manager and the transport operator are part of the same corporate group, as is the case with Turkish Railways TCDD, whereas in the UK, Sweden and other countries the infrastructure manager and the transport operator are completely separate organizations.

In a vertical separation type railway, the top, i.e. the railway operator, pays a track usage fee to the bottom, i.e. the infrastructure manager. In determining this track usage fee, the goal is to balance the expenditure of the infrastructure manager, i.e. the costs of management and renewal, with the income from the transport operator. In some countries, part of the infrastructure manager revenue is covered by government subsidies (Ozawa, Nemoto, 'The role of track usage fees in the vertical separation of European railways', Journal of Transport Studies No. 56, 2012, in Japanese).

(2) Cost burden During Large-scale Disasters: State of Emergency Declarations

For vertically separated railways, in the event of a major natural disaster, the restoration costs will far exceed the normal expenditure of the infrastructure manager. Railway operators are not contractually liable for such extraordinary expenditure.

In the case of the Türkiye-Syria Earthquake that occurred on February 6, 2023, emergency budget measures were implemented based on a state of emergency declaration, and TCDD received recovery funding through national budget allocations. Specifically, Presidential Decree No. 6785 was adopted to declare a state of emergency in the affected provinces under Article 119 of the Constitution of the Republic of Türkiye and Emergency Law No. 2935, which was enforced from 1:00 a.m. on February 8, 2023[18]. In July, the National Assembly adopted a supplementary budget proposal that included additional funding, amounting to 1,119,540,513,000 TL, which corresponded to approximately a 25% increase over the initial budget for the fiscal year[19]. Of this amount, 482,890,000,000 TL was allocated to the Disaster and Emergency Management Authority (AFAD). A portion of the remaining funds were also designated for recovery efforts at TCDD through the Ministry of Transportation Infrastructure. This funding covers all related expenses, including housing construction for disaster victims, food assistance, and infrastructure restoration.

According to the earthquake report issued by the Presidential Strategy and Budget Office in 2023, the estimated cost for the restoration of TCDD's damaged lines was a total of 17.4 billion TL[20]. TCDD will secure a total of 34 billion TL for earthquake-related repair works from 2023 to 2029 through the Ministry of Transportation Infrastructure, with four relevant projects contracted by TCDD in 2023 totaling 6.175 billion TL, being part of the amount, as explained in section 6.2.2. 11 billion TL has been

[18] "State of emergency declared: What does it mean for journalists covering the earthquake?", 09 February 2023, https://www.mlsaturkey.com/en/state-of-emergency-declared-what-does-it-mean-for-journalists-covering-the-earthquake/ (Accessed June 1, 2025)

[19] The 2023 budget of the Republic of Turkey was insufficient, it was added, 07 July 2023

[20] 2023 KAHRAMANMARAŞ AND HATAY EARTHQUAKES REPORT, Presidency of Strategy and Budget. (2023)

allocated for the fiscal year 2024, and 5 billion TL for 2025[21]. It should be noted that due to the significant fluctuations in the TL (Turkish Lira) exchange rate in recent years, conversion to USD or JPY will not be conducted here.

In the case of other countries, governments have incurred restoration costs in response to such large-scale natural disasters. For example, in July 2021, German railways suffered 600 km of track damage due to extensive flooding in Germany, Austria, Belgium and elsewhere. In response to this situation, the German Government announced an agreement to establish a EUR 30 billion reconstruction fund in August of the same year. Of the fund, EUR 28 billion was to be used for the reconstruction of the two affected states, while the remaining EUR 2 billion was to be undertaken by the federal government to cover the costs of building railways, roads, bridges and other infrastructure. (European Economic News, August 12, 2021, 'Germany establishes reconstruction fund for affected areas, contributing a total of EUR 30 billion to support the West')

(3) Legal Basis for Response to Natural Disasters

There are several regulations concerning safety regarding TCDD and TCDD Transport that were issued by the Railway Certification Authority of the Ministry of Transport Infrastructure. Each provides provisions regarding natural disasters, but does not provide specific descriptions.

1) Railway Safety Regulation

Article 7. Basic Requirements and Components of a Safety Management System

(2) The safety management system to be established by all operators includes the following standard components

3) Continuous improvement of the safety management system as a result of risk management,

g) Preparation of emergency action plans: All operators shall prepare emergency plans including information and practical actions to be taken in all kinds of emergencies, accidents and incidents that may occur in railway operations such as derailment, collision, fire, explosion, spread of hazardous chemical substances and natural disasters, accidents and incidents requiring emergency response, struggle, first aid or evacuation. Each plan is reviewed periodically and drills are conducted with all enterprises involved in the accident/incident, relevant units and authorized public institutions.

ğ) Determination of accident/incident investigation methods: All operators shall establish procedures to ensure that accidents, incidents, near misses and other hazardous incidents occurring during their operations are reported and investigated, and that the root cause is investigated and necessary measures are taken and the safety management system is reviewed

[21] Turkey: Ankara keeps rail funds flowing By David O’Byrne, 11 March 2025, Railway Gazette International

2) Regulation on the Determination of the Railway Passenger Transport Lines to be Supported Under Public Service Obligation and the Public Service Obliged Train Operator

Article 38- (1) In order to be used in the evaluation of the qualification to participate in the bidding, the bidder must have a valid railway passenger train operator authorization certificate and Safety Certificate issued by the ministry and these documents must be submitted to the ministry.

3) Guide for Safety Application

This is an instruction manual for the application for safety document submission and registration in the railway sector. It specifies the document formats in detail but does not specify equipment performance, etc.

4) Railway Safety Critical Tasks Regulation

This is a regulation concerning the duties of safety personnel in railways, and it does not specify the required equipment.

5) TCDD Transport General Directorate Insurance Directive

It defines insurance requirements for various situations in railway operations. It cites natural disasters such as earthquakes, volcanic eruptions, storms, floods, and tsunamis as examples, but does not specify disaster prevention.

5.3.3 Urban Railway

Turkish urban railways, represented by the Ankara and Istanbul metros, have the same infrastructure manager and transport operator (except for the Istanbul metro line M11, which is operated by TCDD Transport). These urban railways are legally under the supervision of metropolitan municipalities, as in EU countries, and not directly under the supervision of the Railway Certification Authority UHDGM.
In addition, each metropolitan municipality has its own disaster coordination centre AKOM (Disaster Coordination Centre tur: Afet Koordinasyon Merkezi) and urban railways act in coordination with AKOM in the event of a disaster.

Table 5-3 Comparison of Ankara Metro and Istanbul Metro Disaster Prevention and Response Systems

Item	Ankara Metro EGO	Metro Istanbul
Regulations and standards	- There are internal regulations regarding emergency handling for EGOs (equivalent to Japanese standards for operation and handling practices) and related training is provided. There is no numerical operation management standard that has been set. - Rules have been set, with some supervision by the regulator	- Design standards and operational regulations are in place. - For example, in the event of an earthquake, measures are set for monitoring the situation, limiting speed, suspending operations, etc. depending on the magnitude of the earthquake
Experience in disaster response and recovery	- None	- During the 1999 Marmara Earthquake, operations were suspended and a visual inspection of all lines was carried out over a period of six hours (only M1 Line was operational at that time).
Cooperation with other ministries and municipal authorities	- AFAD and City Hall are responsible for response during and after the disaster (rescue and debris removal); EGO is responsible for daily safety management and maintenance as the railway operator. - After a disaster, there is a temporary EGO response (especially flooding), but AFAD personnel may delegate management authority from EGO after their arrival on site.	- AFAD and metropolitan municipalities handle the response during and after the disaster (rescue and debris removal), as well as equipment inspections.
Deployment of sensors	- AKOM and MGM provide weather information, such as rainfall. - AKOM issues warnings and provides radar rainfall data that is published on the MGM website. - EGO's own sensors for earthquakes, floods, etc. are not possible due to budgetary	- Natural disaster scenarios are created and the necessary weather sensors are prepared. - Sensor costs are borne by Istanbul Metropolitan Municipality and data is also used for sectors other than railways.

Item	Ankara Metro EGO	Metro Istanbul
	constraints	
Future plans	- Efforts are being made to improve disaster prevention facilities to be applied when new lines are constructedt, but there are no plans regarding improvements to existing lines.	- Gas and electricity are automatically switched off in the event of an earthquake. Automatic train operation shutdowns are being installed on three line sections. - There are plans to install sensors, seismometers and rain gauges at 50 locations.

Source: Survey team compilation based on interviews and documents.

(1) Ankara Metro EGO Interview Results

On June 27, 2024, JST visited the EGO headquarters and held discussions on the current status of EGO and its response to disasters. Subsequently, they visited the rail depot near Macunkoy station and the operations management center there.

EGO fully took disaster preparedness into account when designing and constructing the line, and has implemented few additional measures. EGO assumes support from the Ankara Metropolitan Municipality in the event of a disaster, which has a good track record. Cooperation with the central ministries and AFAD appears to be minimal.

1. Overview of Emergency Management in EGO.

a.) An Emergency Operation Procedure (equivalent to the Japanese Operational Handling Code of Practice) has been developed for internal EGO use, first published in 1997 and the current version updated in 2017, with 156 pages. The Procedure will also be updated in line with the the facilities upgrades (opening of M4 Line). Relevant training on emergency response has also been conducted.

b.) The Procedure does not set numerical operational control standards, but is clearly stated as an internal regulation for a certain degree of defined handling. The rules are also set with a certain degree of supervision by the regulatory authorities.

c.) EGO has not received any direct instructions from AFAD or the Ministry on disaster management. Evacuation drills are occasionally conducted with guidance from the relevant authorities. In addition, AFAD has requested information from EGO to check their capacity for disaster management response.

d.) Evacuation drills are conducted approximately twice a year in case of emergency situations such as fire, hostage rescue, etc.

e.) Response during and after a disaster (rescue and debris removal) is handled by AFAD and city governments; EGO, as the railway operator, is responsible for daily safety management and maintenance. In the event of a disaster, EGO will temporarily respond (especially flooding), but personnel from AFAD may be delegated with management authority by EGO after their arrival on site.

f.) The seismic rating of EGO civil structures and equipment is set at a level that prevents collapse for earthquakes of up to magnitude 9. As Ankara is not a high seismic risk area, routine earthquake preparedness is not specifically considered. The expected design life of the infrastructure is 100 years.

g.) The number of occurrences is recorded by disaster type, but data cannot be shared with JST.

h.) The Operation Control Centre (OCC) on M1 Line is located at the depot near Macunkoy Station and in the event of an anomaly, operations can be continued by a spare OCC located in the Koru depot, the line's terminus. The Ankaray line has no spare OCC.

2. Flood and earthquake disaster management in EGO.

a.) The disaster type with the highest priority is flooding. There are no structural measures such as watertight boards or watertight doors, and there are no earthquake or flood detection sensors.

b.) There is a flood prevention plan in place at each station (Note: no actual plan was identified).

c.) EGO is testing a different type of flood prevention equipment that will serve as a water stop device at the ventilation openings. This equipment is different from the flood prevention equipment in Japan.

d.) Flood warning thresholds are not explicitly set and rely on visual inspection by the train driver. The operation is suspended on sections where the water level on the line reaches above the third rail, which is used for vehicle power.

e.) AKOM and MGM information is used for rainfall and other weather information. AKOM issues warnings and radar rainfall data is made available on the MGM web site.

f.) The decision to suspend operations due to flooding or earthquakes is made by EGO's Operation Control Centre (OCC). The decision to suspend operations requires the approval of several senior managers.

g.) Although there are disaster management plans, such as the Arakawa River Timeline in Japan, which take into account cooperation with relevant ministries and the Ankara Metropolitan Municipality, in reality the role of the railway operators is limited.

3. The role of EGO in damage assessment and disaster recovery

a.) EGO carry out damage assessments of structures with engineers within the organization. To date, there has been no experience of receiving assistance from external agencies (e.g. other ministries, research institutions, etc.).

b.) There is no track record of disaster rehabilitation of structures, as there have been no major disasters since the start of operations.

4. Budget of EGO

a.) EGO operates on the budget of the Ankara Metropolitan Municipality and has a track record of financial support by the Ankara Metropolitan Municipality for the purpose of project and programme implementation. EGO does not receive any government budget.

5. Other matters to be checked

a.) In addition to being the railway operator, EGO also plays the role of railway infrastructure manager.

b.) The legislation for the development of tunnel disaster prevention (fire protection) is based on US NFPA 130.

c.) Ankara Metro's operational management system is GOA2 based on CBTC, and GOA1 uses a track circuit type signalling system.

d.) The average daily ridership of the Ankara Metro is around 600,000 passengers per day.

e.) Passenger safety education (e.g. safety brochures) has not been implemented, but is planned to be implemented in the future.

f.) Vehicle maintenance work is carried out on a distance basis.

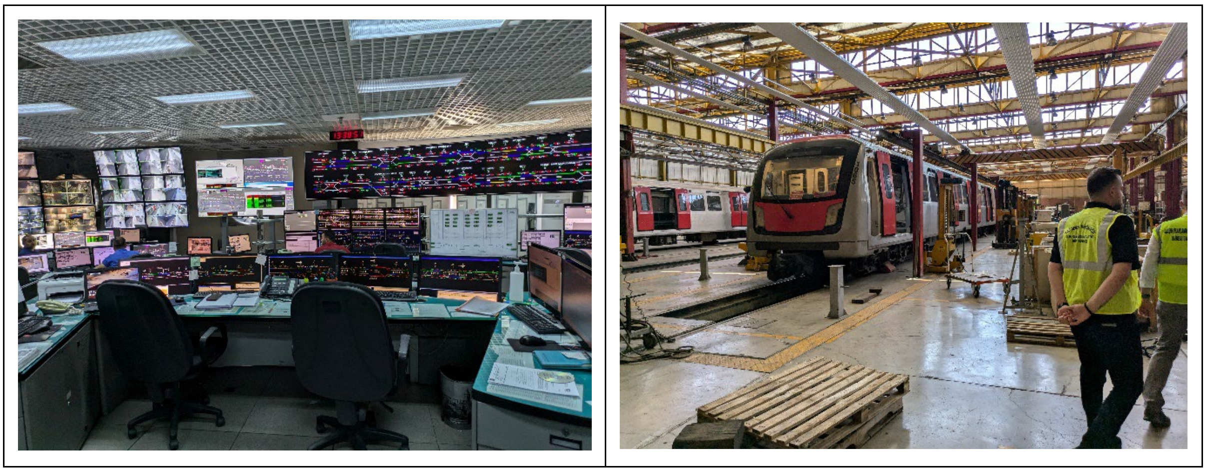


Photo: JST

Figure 5-12 EGO (Left: OCC, Right: Depot)

(2) Metro Istanbul Interview Results

On June 28, 2024, the team visited the depot of the Metro Istanbul M1 Line and learned about the current situation of Metro Istanbul, its response to disasters and other issues, and the state of vehicle maintenance.

1. Questions sent to Metro Istanbul and their answers

Note: The following questions did not always receive the expected answers, however, together with the interviews and the presentation by Metro Istanbul, the results were almost exactly what JST's expectations.

a) Does Metro Istanbul use earthquake-resistant structures?

→ The Istanbul Metropolitan Municipality is in charge of design and construction.

b) Does it have disaster response equipment? Are there any plans to introduce them?

→ No, Metro Istanbul does not have any (note: we respond as an organization, as shown in Metro Istanbul's presentation material below, but we do not have any specific hardware).

c) Do you have seismometers, rain gauges and rail thermometers? And are there any plans to introduce them?

→ Metro Istanbul does not own them as Metro Istanbul (Note: we own them as a metropolitan municipality).

d) How many disaster response staff does Metro Istanbul have?

→ 1,500 people are engaged in safety direct link operations.

e) Who decides to suspend rail services in the event of an earthquake or heavy rainfall?

→ The Government Emergency Agency AFAD, the Disaster Coordination Centre of Istanbul Metropolitan Municipality organisation AKOM, Metro Istanbul Emergency Management and the metro command centres make the decisions.

f) A list of the location and scale of natural disasters should be provided to the Japanese side.

→ Cable cars and coastal stations and lines are monitored. (No specific list was provided.)

g) Are there any government subsidies for natural disaster response?

→ This is carried out under the budget of the Istanbul Metropolitan Municipality.

h) Are there government subsidies for the restoration of railway facilities in the event of an earthquake?

→ This is implemented in the budget of the Istanbul Metropolitan Municipality.

i) Do you have an equipment monitoring system for natural disasters?

→ The Istanbul Metropolitan Municipality as a whole is planning to introduce a monitoring system.

j) What are the contracts and process management arrangements with contractors implementing natural disaster recovery?

→ The Istanbul Metropolitan Municipality designs and implements the work.

k) What is the relationship between Metro Istanbul and the Government?

→ AFAD represents the Government.

l) Are there any design standards used for design and implementation during natural disaster recovery?

→ The Istanbul Metropolitan Municipality will carry out the design and construction.

m) What is the relationship between Metro Istanbul and AFAD?

→ Monthly meetings are held and drills are conducted every six months.

n) Are there any measures to finance the cost of restoration after natural disasters from outside Metro Istanbul?

→ Damage assessments are carried out jointly by Metro Istanbul and the Istanbul Metropolitan Municipality.

o) Is there a system for monitoring the condition of structures after natural disasters?

→ Metro Istanbul does not have such a system

2. Results of interview with Metro Istanbul

Sensors for earthquakes and mechanisms for stopping and resuming operations.

- When the Marmara Earthquake occurred in 1999, all train lines were halted and all facilities on all lines were checked by humans over a period of six hours. No sensors were installed at that time.
- In Istanbul, city gas and electricity supplies are automatically shut down in the event of an earthquake. The metro is also about to implement automatic metro and train shutdown.
- With regard to natural disasters, the necessary sensors have been deployed according to the scenarios studied in advance.
- The Istanbul Metropolitan Municipality has installed weather sensors, which are used not only for railways but also for other purposes. The Istanbul Metropolitan Municipality funds the installation of the sensors. Sensors are selected and installed according to technical standards; MGM data is not used.
- Future plans include equipping 50 locations with sensors, seismometers and rain gauges.
- The technical standard for the sensor system is well known by the advisor, Dr. D., and there is a standard that TCDD also uses. The specific sensors, installation locations and quantities have not yet been finalized, but some have been decided. To some extent, information can be made available to JST.
- The installation of sensor systems is not audited by UHDGM. The Istanbul Metropolitan Municipality has the authority to permit them; the Marmaray Line operated by TCDD and M11 Line connecting the airport are managed by the Ministry of Transport and Infrastructure, while the other lines are owned by the Istanbul Metropolitan Municipality.
- For the earthquake response plan, the monorail system has four sensors and carries out its own planning, data collection and analysis.
- If a train stops between stations on the monorail, it proceeds at low speed according to EU standards, and if it fails to reach the station, the driver guides the passengers.

b) Disaster response and restoration

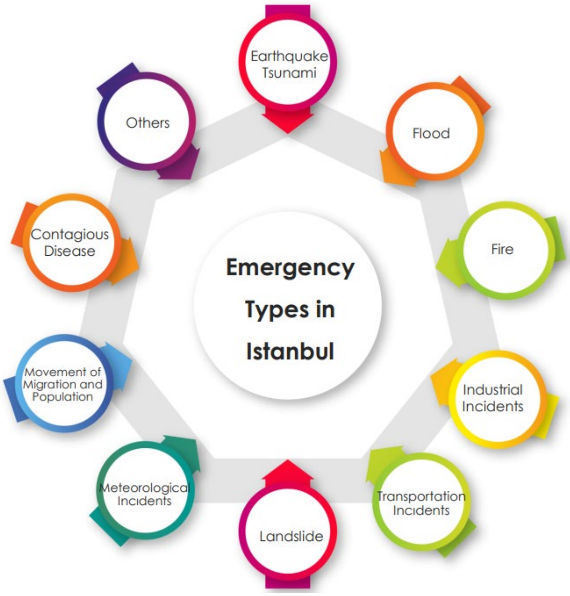
- AFAD provides 23 services, one of which is damage assessment in disasters. TCDD checks its own lines, and highway operators check their own highways. In practice, AFAD and the operators may be working together in some respects.
- As a general rule, the Istanbul Metropolitan Municipality pays for and works on the restoration following natural disasters. If a long period of time is required, the government will come to its assistance.

c) Disaster prevention sensor system and field test concept in Japan

- Metro Istanbul asked the survey team about the MTBF of the sensor system. The survey team responded that the system's dust and water resistance standard is IPX65 and that it has a 5-year product life, which is considered long in terms of hardware, but that there were no figures available in terms of the Mean Time Between Failure.

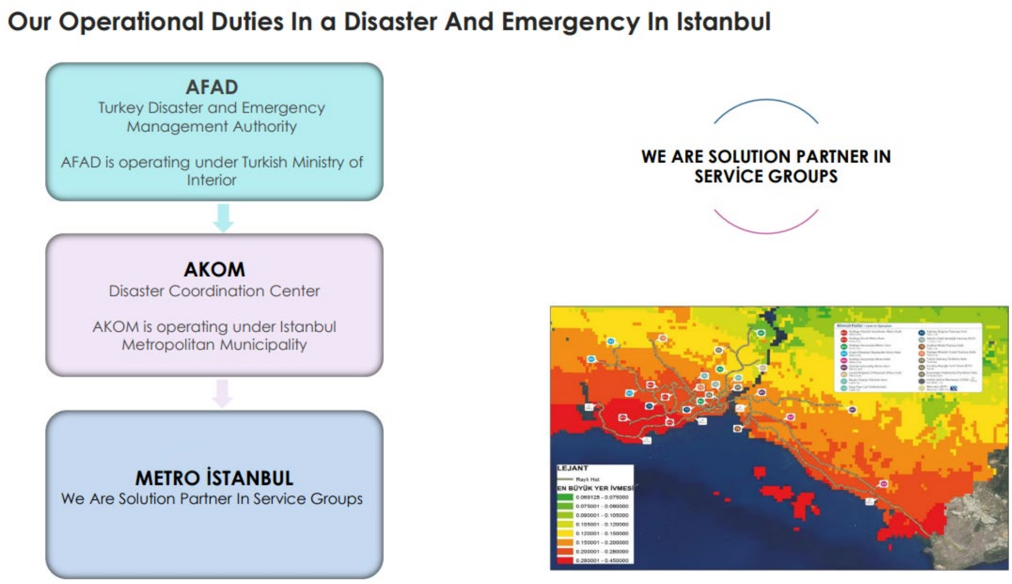
3. Excerpts from Metro Istanbul presentation material

Metro Istanbul envisages 10 different emergency situations, including human ones (Figure 5-13). Specifically, these are: earthquakes/tsunamis, floods, fires, industrial accidents (e.g. toxic gas outbreaks), traffic accidents, landslides, other weather hazards, migration and population movements, epidemics, other.



Source: Metro Istanbul data

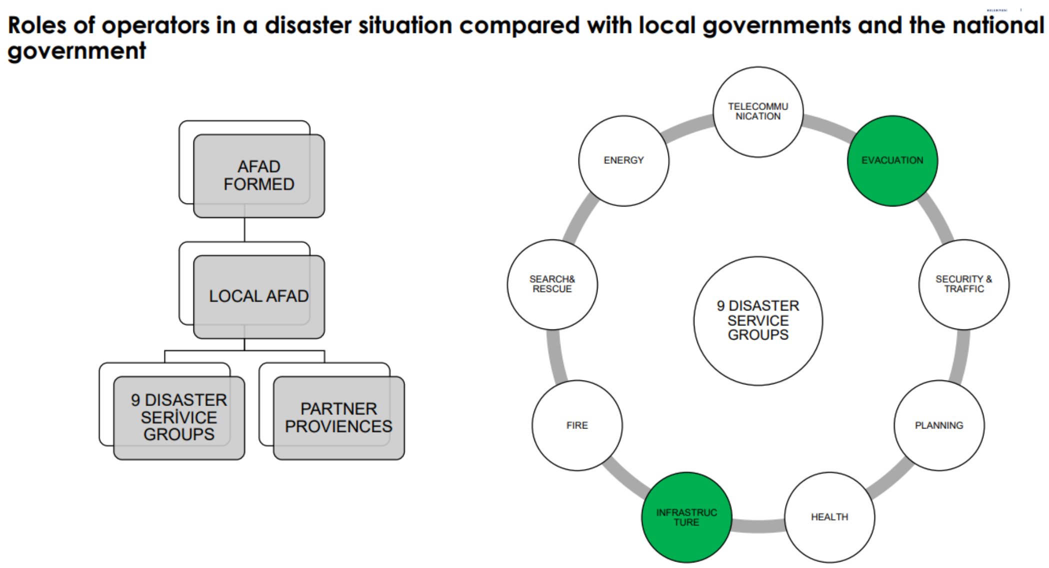
Figure 5-13 Emergencies Envisaged by Metro Istanbul (Including Non-Natural Disasters)



Source: Metro Istanbul material.

Figure 5-14 Relationship between AFAD, AKOM and Metro Istanbul

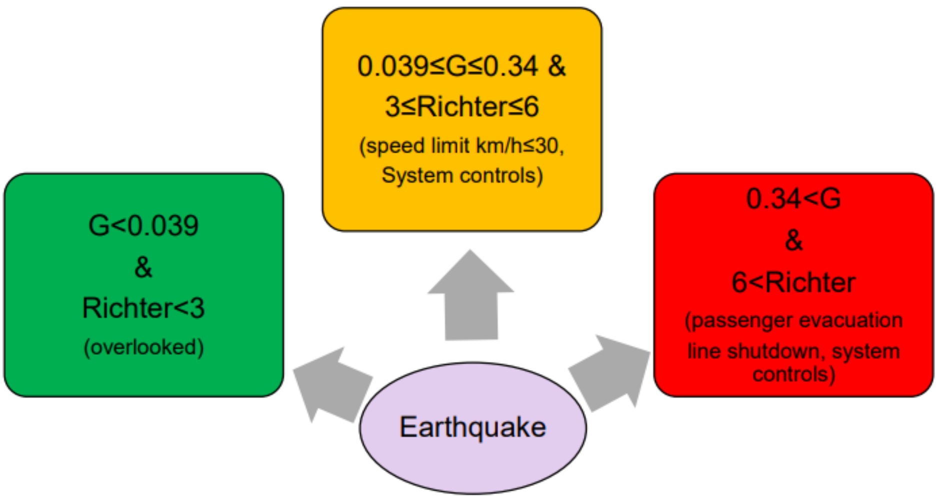
The framework is based on a three-tier cooperation between the government agency AFAD, the Disaster Coordination Centre AKOM, an organization of the Istanbul Metropolitan Municipality, and Metro Istanbul to deal with the situation (Figure 5-14).



Source: Metro Istanbul material.

Figure 5-15 Role of Government and Local Authorities in the Event of a Disaster

AFAD responds to disasters in cooperation with the nine disaster response departments of the local AFAD, which are subordinate to the government AFAD, and the metropolitan (or municipal) authorities. Each of the nine disaster response departments involves relevant organizations and is assigned with the following responsibilities: evacuation, security and transport, planning, health, infrastructure, fire, search and emergency, energy and communications. Metro Istanbul is addressed by Evacuation and Infrastructure Department.



Source: Metro Istanbul material.

Figure 5-16 Operation Rules in Metro Istanbul in the Event of an Earthquake

In the event of an earthquake, there are provisions for a three-stage response depending on the observed scale (Richter scale): monitoring, speed restriction to 30 km/h or less, and passenger evacuation and suspension of operations.

4. Depot observation
Since its opening in 1988, the depot has managed more than 300 vehicles of 18 different types, using both time-based and distance-based management depending on the type of vehicle. Modification work, such as the installation of air-conditioning units, is designed and constructed on an independent basis.

5. Observation visit to the R&D center
At Metro Istanbul, a wide range of railway equipment is being independently developed at the R&D center located in the depot, from the design and manufacture of new rolling stock to railcar brake inspection equipment, station passenger guidance equipment, in-train path setting equipment, automatic wheel and rail lubricant application equipment and moving rigid overhead wires. Sixteen of the designed rolling stock are in operation and 34 newly designed rolling stocks are planned to be manufactured.

(3) Comparison of TCDD and Urban Railways

Based on the conducted interviews, JST compared the disaster preparedness and response systems between Turkish State Railways TCDD and the Ankara Istanbul Urban Railway.
Urban railways, such as Ankara Metro EGO and Metro Istanbul, are part of the metropolitan municipality and are incorporated into the national and metropolitan municipality's disaster management system. These systems have a defined division of roles, which enables them to respond to disasters effectively according to their scale and nature.
In contrast, TCDDs are outside the national disaster management system and are required to cope with disasters independently, from detection to recovery.

Table 5-4 Comparison of TCDD and Urban Railways' Disaster Prevention System and Response

Item	TCDD	Urban Railways
Management structure	- Vertically separated railway: infrastructure company and operator (EU standards)	- Same infrastructure company and operator - Upper and lower integration
Supervisory authority	- Directorate General for Service Regulation (UHDGM), Ministry of Transport and Infrastructure	- Ankara and Istanbul Metropolitan Municipality
Accident Investigation Body	- Accident Investigation Committee (UEIM). UEIM personnel seconded from TCDD	- Ankara Istanbul Metropolitan Municipality
Safety Standards	- Safety standards issued by TSI (Technical Standards for Interoperability in Europe) and UHDG (applicable only in Türkiye)	- Independently established (reports are made to UHDGM)
In the Event of a Disaster	- Self-help	- Cooperation with AFAD and AKOM - Response during and after the disaster (rescue and debris removal) is handled by AFAD and metropolitan municipalities. Equipment inspections are also handled by AFAD
Disaster Recovery Costs	➢ Own recovery, additional budget allocated by Ministry of Transport and Infrastructure ➢ In case of a large-scale disaster, there are examples of national budget allocations based on a state emergency declaration.	- Metropolitan area municipalities bear the costs. - Government aid envisaged for larger scale cases (there are no examples yet).
Response to earthquakes	- Self-reliant - Sensors in high-speed railways but not used effectively. - MGM (Meteorological Agency) data not used	- Ankara facilities are prepared for magnitude 9 earthquakes. Sensors are not possible due to budget constraints. - Istanbul has experience of post-earthquake walk-in inspections. Gas and electricity automatic shutdown

Item	TCDD	Urban Railways
		systems for earthquakes are in place; automatic shutdown of railways is still under study.
Flood response	- Self-supporting - MGM (Meteorological Office) and DSI (Water Authority) data not used. - UEIM investigates cases of accidents from disasters such as derailments, and some cases have led to court cases	- MGM (Meteorological Office) data is not being used. - Istanbul has developed natural disaster scenarios and prepared the necessary weather sensors. Sensor costs are borne by the metropolitan municipality, and data is also used outside the railways. - Ankara has implemented measures to stop water at ventilation openings, etc.

Source: Compiled by the research team based on interviews and documents.

5.4 Issues Related to the Development of Laws and Regulations

The centralized implementing agency for disaster management in Türkiye is AFAD, and there is a TARAP at the national level regarding disaster prevention and mitigation, and an IRAP, which is a disaster prevention and mitigation plan at the provincial level. In addition to these, the TASIP, which provides direction for reconstruction, was announced in January 2023.

In Japan, the Basic Law on Disaster Countermeasures requires the formulation of local disaster management plans not only by the national government, but also by prefectures and municipalities. As mentioned above, in Türkiye, Article 53 of the Municipalities Act stipulates the formulation and implementation of response plans and contains provisions for emergency response to fires and disasters. Although this article does not prohibit the formulation of plans for disaster prevention and mitigation plans, the interviews conducted through the detailed planning survey and the information published by the municipalities did not confirm any plans for emergency response besides the municipality's own disaster mitigation plans.

The content of the measures in the municipalities' strategic plans and performance programs shows that disaster prevention and mitigation measures are limited in terms of budget size, with only urban improvements, awareness-raising activities by the fire department, disaster drills and post-disaster response being undertaken.

In this context, IRAP is currently the basis for the preventive disaster prevention and mitigation efforts of local authorities, and its characteristics give the impression that it emphasizes hazard analysis for each type of disaster. Particularly, one of the essential issues of IRAP is that it involves many stakeholders and sets out a wide range of measures, but because it is not legally binding, there is no budgetary support and implementation has been stagnant. In addition, it is inefficient to have central leadership in the formulation and implementation of municipal disaster prevention and mitigation plans, and in the future, it will be necessary to develop legislation requiring municipalities to take the lead in implementation, and to work towards strengthening the capacity of municipalities to enable them to formulate such plans.

In view of the four priority actions of the Sendai Framework for Disaster Reduction, it can be seen that a certain degree of progress has been made in (i) understanding disaster risk in the Sendai Framework for Disaster Reduction, as efforts are being made to identify disaster hazards and risks through the development of IRAPs, while future progress remains to be made in (ii) strengthening disaster risk management, (iii) investments in disaster risk enhancement for resilience and (iv) strengthening disaster preparedness for more effective response and 'better reconstruction' to achieve recovery, restoration, and reconstruction.

On the other hand, looking at the recovery after the February 2023 earthquake, it is noted that there is also a difference in organizational and institutional capacity between metropolitan municipalities (e.g. Kahramanmaraş) and general municipalities (e.g. Adıyaman), although it is not possible to make a general comparison as the damage situation is different.

The growing importance of disaster prevention and mitigation can be seen from the 12th National Strategic Plan published in October 2023. The five priority areas for the country in the plan are: (i) stable and strong economy, (ii) competitive productivity and manufacturing, (iii) quality human resources and strong society, (iv) disaster-resilient living areas and sustainable environment, and (v) governance by law and good governance. These are the same as those in the 11th National Strategic Plan, except for (iv), the conventional 'livable cities and sustainable environment' was revised to 'disaster-resilient living areas and sustainable environment'. In the 11th Plan, urban transformation and disaster management were listed as the fourth and eighth, respectively, of the eight items related to disaster prevention and mitigation, but in the 12th Plan, disaster management is listed first, and urban transformation is listed second (the content of the eight items is the same), which is thought to indicate the growing importance on disaster prevention and disaster mitigation considering the February 2023 earthquake.

The 12th Plan emphasizes or adds to the following areas in the light of the earthquake: strengthening efforts for major disasters and disaster mitigation, revision of the legal framework, comprehensive resilience strengthening of cities and infrastructure, revision of IRAP, disaster management capacity assessment and reconstruction of disaster-affected areas. The following points need to be noted. It is necessary to check the new strategic plan of AFAD to see what specific initiatives these items envisage, but efforts should also be made to secure budgets for the realization of disaster prevention and mitigation measures and projects by local authorities, keeping a close eye on the changing direction and priority measures of AFAD, MoEUCC and other disaster management-related ministries and agencies.

Thus, disaster management at the national level in Türkiye, centered on AFAD, has been steadily developed both in terms of legislation and organization. Urban railways such as Ankara Metro EGO and Metro Istanbul, as part of the metropolitan municipalities, are incorporated into the national and metropolitan municipalities' disaster management systems. These operators have clearly defined roles and responsibilities that enable them to respond to disasters according to the scale and nature of the event.

In contrast, TCDDs are outside the national disaster management system and are required to cope with disasters independently, starting from detection to recovery. As described in 5.4.2 (2), in cases of large scale disasters like the Türkiye-Syria earthquake, allocations to the TCDD through the Ministry of Transport and Infrastructure's national budget based on the government's state of emergency declaration have been made, allowing TCDD to undertake restoration work. However, disaster prevention and detection are being handled independently by TCDD.

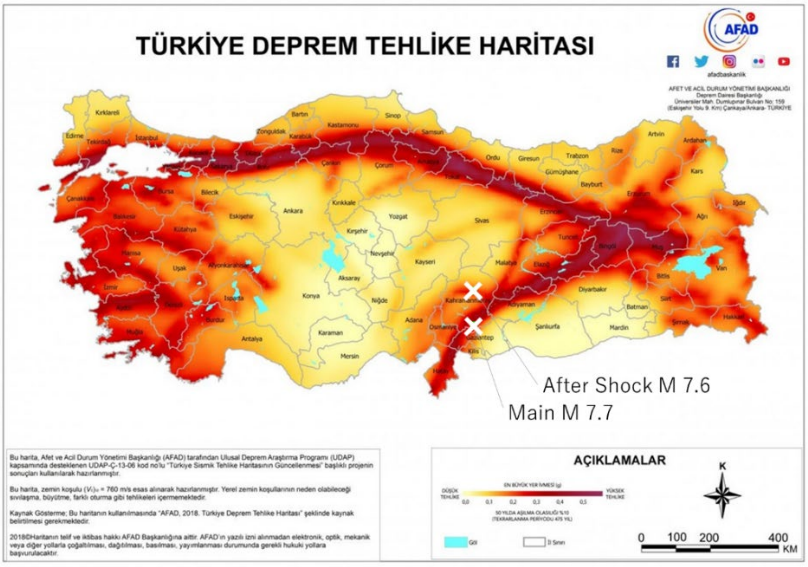
Chapter 6 Status of Railway Restoration and Issues at Sites

6.1 Restoration Status of the Railway Civil Structures Damaged by the Earthquake

6.1.1 Overview of the 2023 Türkiye-Syria Earthquake

At 4:17 a.m. on February 6, 2023, a magnitude 7.7 earthquake with an epicenter at a depth of 8.6 km on the border between Gaziantep and Kahramanmaraş provinces (37.288°N, 37.043°E, 30 km south-southwest of Kahramanmaraş) occurred (depth and magnitude of the epicenter are from AFAD). Nine hours later, at 13:24, a magnitude 7.6 earthquake (aftershock) occurred at a depth of 7.0 km, south-southeast of Ekinej, Kahramanmalash (38.089°N, 37.239°E, 60 km northeast of Kahramanmalash) (Ibid.). The earthquake caused great damage, with approximately 51,000 people killed and 107,000 injured.

The four plates of Eurasia, Anatolia, Africa, and Arabia collide in the vicinity of Türkiye, and the earthquake caused a lateral displacement of up to 11 m at the East Anatolian Fault, the boundary between the Anatolian and Arabian plates, and a maximum lateral displacement of about 4 m also reached the ground. Maximum acceleration exceeding 1g (9.8 m/s2) and maximum velocity exceeding 1m/s were observed in both the main quake and aftershocks, causing extensive damage. [22, 23, 24, 25]



Source: JST added the epicenter to the AFAD earthquake hazard map

Figure 6-1 Epicenter of the Türkiye-Syria Earthquake

22 Preliminary Recconnaissance report on February 6, 2023, Pazarık and Elbistan Mw=7.6, Kaharamanmaraş Türkie Earthquakes, Edited by: Kemal Önder Çetin, Makblule Ilgaç, Gizem Can and Elife Çakır, February 20, 2023, REPORT NO: METU/EERC 2023-01, MIDDLE EAST TECHNICAL UNIVERSITY

23 P. Martin. Mai et al : The Destructive Earthquake Doublet of 6 of February 2023 in South-Central Türkiye and Northwestern Syria: Initial Observations and Analyses, The Seismic Record, A Journal of the Seismological Society of America, May 2023

24 Report on Turkey-Syria Earthquakes, 6 September 2023, Asian Disaster Reduction Center

25 Geospatial Information Authority of Japan, 52nd debriefing session (June 1, 2023)

Damage to transport infrastructure included the disruption of the railway line between Malatya and Iskenderun, liquefaction in the port of Iskenderun, and damage to the road network in the affected areas. In particular, tunnels, bridges, and other civil structures on the railway line were damaged. In addition, deformation of the track bed due to liquefaction derailment of rolling stock was observed.

The earthquake motion, liquefaction, ground cracks, ground deformation, rock falls, and slope hazards were the cause of damage to railway destruction and derailments.

Derailment of rolling stock included one passenger train, four locomotives, and 30 freight wagons. All of these vehicles were owned by TCDD Transport. Damage was also observed on high-speed rail lines that were under construction. The table below summarizes the earthquake damage to the rail network (Table 6-1).

TCDD has 1,275 km of operating lines in the affected area between Adana - Hatay - Osmaniye - Gaziantep - Kahramanmaraş - Malatya. In particular, the Sivas-Malatya-Iskenderun route is an important freight route for goods and mineral resources in Türkiye.

According to TCDD statistics, the Malatya- Fevzipasa station, located at the center of the currently disrupted section, transported 1.88 billion net ton-km of freight in 2022, the highest value for any section in Türkiye. During the suspension of the line, freight trains were operated from Malatya via Sivas and Kayseri, increasing the distance by about 500 km.

Source: Ömer AYDAN, Reşat ULUSAY "A QUICK REPORT ON PAZARCIK AND EKİNÖZÜ EARTHQUAKES (TÜRKİYE) OF FEBRUARY 6, 2023"

Figure 6-2 Derailment Due to the Earthquake (Left: Gölbaşı Station, Right:Fevzipasa Station)

Source: TCDD

Figure 6-3 Landslides and Rock Fall Near Fevzipasa Station

Table 6-1 Overview of the Damage to the Railway Due to the Türkiye-Syria Earthquake

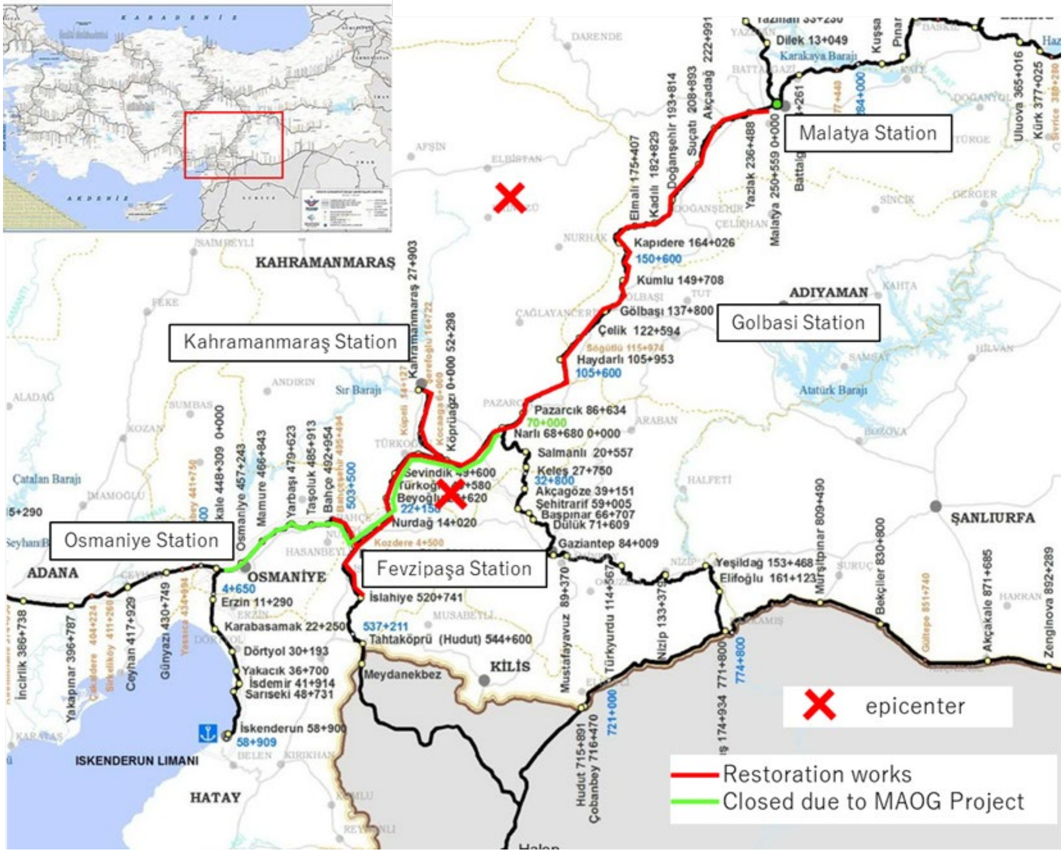
Damage	Description	Cost estimated（TL）
Civil engineering structures (8 sections)	Deformation of tunnel Landslide and slope related Super-structures Electric equipment	17,400 million TL
Rolling stock	Derailment	19.6 million TL
High standard line (Under construction)	Tunnel (under construction)	260 million TL

Source: Presidency of Strategy and Budget “2023 KAHRAMANMARAŞ AND HATAY EARTHQUAKES REPORT”

6.1.2 Railway Sections Suspended Due to the Earthquake Disaster

The total length of railways in the earthquake affected area was 1,275 km. The Malatya - Narlı - Iskenderun corridor was an important freight transport route from mines in south-eastern and eastern Türkiye to the port of Iskenderun, with an annual transport volume of 8 to 10 million tons.

Of this section, the Narlı -Gaziantep-Nizip and Iskenderun-Osmaniye-Baçhe track were repaired over the three weeks following the earthquake and have resumed operation. The 250-km Fevzipaşa -Malatya, 28-km Keplaguz-Kahramanmarash, 18-km Fevzipaşa- Baçhe, and 9-km Fevzipaşa -Israhiye sections are still under repair as of March 2024, one year after the earthquake. The Narlı - Fevzipaşa - Bache section overlaps the construction section of the Mersin - Adana - Osmaniye - Gaziantep (MAOG) high-speed rail project, and as of March 2024, the reason for the suspension is due to the high-speed rail project.



Source: JST added the epicenter to TCDD data

Figure 6-4 Lines Currently Out of Service

The 250-km line between Fevzipaşa and Malatya is half of the 504-km Fevzipaşa-Diyarbakır line, which opened in 1935. The line was built to transport copper ore mined near Diyarbakır and was electrified in 1994. Passenger trains made only one round-trip per day, and freight trains were the main service. The long-term plan for the Marathialar-Narlu Line (182km in length), which was severely damaged by the earthquake, also includes the concept of increasing the speed of the line (2024-2028 TCDD Strategic Plan (2022)).

It was observed that the entire line was suspended and the track was being reconstructed from the roadbed, which is thought to serve as an improvement related to this project.

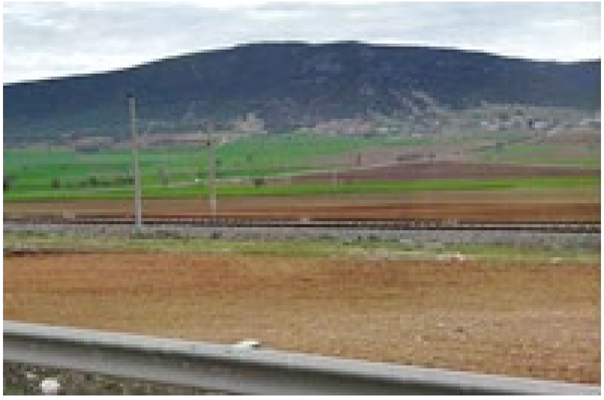


Figure 6-5 Section With Repaired Track

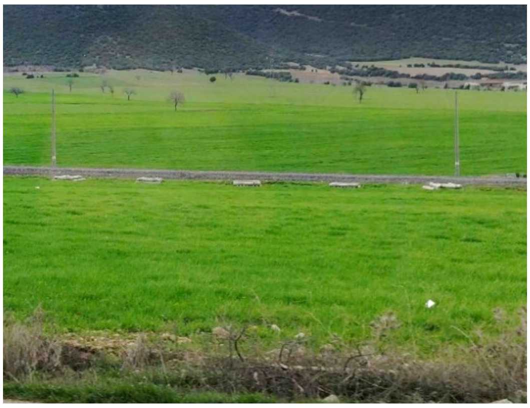


Figure 6-6 Section Prepared for Railway Sleeper Installation

Figure 6-7 Railway Crossing Where Track Was Removed

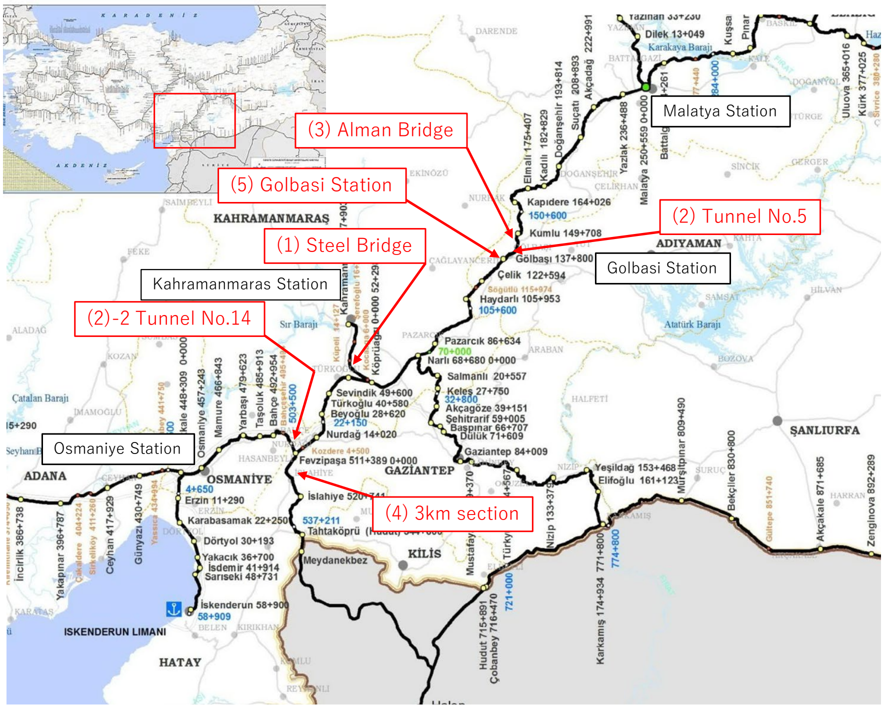
Figure 6-8 Building With Damage Due to the Earthquake

6.1.3 Railway Structures for Which the May 2023 Survey Team Proposed Restoration Methods

In March 2023, JICA dispatched a team of experts from the Japan International Cooperation Agency (JICA) to assess the extensive damage caused by the February 6, 2023 earthquake in Türkiye. The team's report on their return to Japan suggested the possibility of providing technical assistance for the restoration of railway bridges and tunnels. In response to this recommendation, the Ministry of Land, Infrastructure, Transport and Tourism's Railway Bureau and JICA requested that JR East, with its expertise in earthquake restoration, provide consultation on restoration policies for civil structures that TCDD felt would be difficult to restore. In response to this request, engineers from JR East accompanied a survey team led by JICA from April 30 to May 9, 2023 (including three days of on-site survey) (May 2023 survey).

By the time of the May 2023 survey, approximately three months had passed since the earthquake, and TCDD's restoration policy had largely been established and restoration work had already begun in some damaged areas. Therefore, in the May 2023 survey, the team decided to target structures that TCDD considered difficult to restore and wanted advice on restoration policies from experts from JR East. The target was six structures of the five types shown in Figure 6-9.

In the May 2023 survey, experts examined the damage to these structures, estimated the causes, and proposed restoration plans (Table 6-2).



Source: JST added the surveyed areas in May 2023 to the TCDD data.

Figure 6-9 Surveyed Areas in May 2023

Table 6-2 Causes of Structural Damage and Proposed Restoration Measures Indicated by the May 2023 Survey

Structure	Damage situation	Cause	Proposed restoration plan
Steel bridge 	The girder moved perpendicular to the track and the shoe was damaged. The end girder came into contact with the movable shoe seat, and the end girder broke.	Earthquake motion gave upward lift on the girder, causing it to move beyond the side blocks of the shoe.	There was no unrecoverable damage to the main structure of the girder, so some parts were replaced and it was moved to its original position.
Tunnel 	Continuous compression failure on the tunnel crown. Cracks, shifts, and voids in the masonry at the entrance of tunnel.	Deformation of the ground due to the earthquake, and cavities behind the lining at the tunnel crown	Spalling prevention work and backfill injection to the crown of the tunnel. Combining spalling prevention work and cement injection on masonry arches
RC bridge 	Cracks and chips in the piers causing the cross-sectional load capacity to become insufficient	Vertical and eccentric axial forces acted on the arch base, causing cracks in the unreinforced structure.	Wrapping unreinforced concrete column bases with RC
Earth structure 	Large-scale rock collapse	Rain and snowmelt loosened and fragmented the rock, causing cracks, which were then enlarged by earthquake motion.	JST proposed countermeasures that include not only structural measures such as rock fall protection equipment, but also non-structural measures.
Track structure 	Large track deformation occurred due to subsidence of the roadbed and ballast.	Lateral flow due to liquefaction	Driving sheet piles on both sides of roadbed and injecting chemicals to make the ground denser

Source: Prepared by JST based on the May 2023 survey results.

6.1.4 Restoration Status of Damaged Railway Structures Proposed in the May 2023 Survey

This section reports on the survey outline and proposal made in the May 2023 survey for each structure and the survey on the restoration status of the site conducted by JST on February 26 and 27, 2024.

a) Gölbaşı Sta.

There are several lakes in the vicinity of Gölbaşı Station, and the groundwater level is about 2 m below the ground surface in the vicinity of the station, according to the Turkish National Railways staff member who explained the situation during the May 2023 survey. In this survey, despite the clear weather, several streaks of surface water were observed from the roadside slope to the lake, suggesting that the groundwater level is very high.

In the survey conducted in May 2023, damage around the Gölbaşı station was observed as a lowering of the ballast due to roadbed subsidence and cavities under the sleepers. Several areas where the track had been deformed significantly and overhung were observed toward the end of the station. The high groundwater level around the station, traces of liquefaction, and the large curvature of the track due to the settlement of the roadside structure and displacement to the railway side suggest that the cause of the damage around Gölbaşı Station was the occurrence of lateral flow due to liquefaction.

The restoration plan proposed in the May 2023 survey suggests that the restoration of roadbed subsidence should be prioritized and restoration specifications should be selected in consideration of the budget and construction period, because the affected distance is long. As a countermeasure for lateral flow caused by liquefaction, the authors propose two methods: (1) sheet piling both sides of the embankment and fixing the heads of the sheet piles by connecting them with tie rods, and (2) improving the density of the ground by cracking and injecting chemicals into the sandy soil under the embankment (leaf vein shape grouting).

In this survey, the track around Gölbaşı Station had only been removed, and no significant restoration work had been done. A heavily deformed track section was preserved on the Malatya side of the station (Figure 6-10).

At the end of January 2025, it was reported by the press that the construction of the Gölbaşı Station was completed[26]. The photos from the report showed the roadbed being replaced with concrete (Figure 6-11), as well as the progress of the work (Figure 6-12).

[26] https://www.aa.com.tr/tr/gundem/depremlerde-hasar-goren-golbasindaki-demir-yolu-hattinin-onariminda-sona-gelindi/3465189 (Accessed April 14, 2025)

Source: JST

Figure 6-10 Large Deformed Track Near Gölbaşı Station

Source: AA

Figure 6-11 Restoration of the Roadbed at the Maratya Side of Gölbaşı Station

Source: AA

Figure 6-12 Replacement of Roadbed of Gölbaşı Station Area

b) Tunnel No.3

No specific restoration plan for No. 3 tunnel was presented in the May 2023 survey. The damage to the tunnel was described as follows: the tunnel lining had collapsed in the middle of the tunnel, causing sediment to flow into the tunnel, and the slope at the end of the tunnel showed signs of a landslide. Based on observations of the inflow of sediment at the site and samples taken from the boring core directly above the collapsed site, it was estimated that the ground was in a very bad condition, with weathering of the rock extending down to the bottom of the tunnel.

At the time of this survey, the tunnel restoration work had just been completed. The section on the starting point of the tunnel was excavated without a lining and had not been damaged by the earthquake. The middle part of the tunnel was being restored using the NATM (Figure 6-13 to Figure 6-14). Because fore-poling was performed on the outer upper part of the original cross section, the excavated area of the tunnel was increased from the original tunnel.

The cross-section of the NATM is an encompassing section of the original tunnel cross-section. Fore- poling is used for excavation to prevent collapse of the upper section. In order to fore-pole the upper section without a face, excavation faces of holes for poling are provided at intervals of 4.5 m. In addition, the rear of the excavation face needs to be excavated so that steel rods can be inserted, so the cross section repeatedly expands and contracts at 4.5 m intervals in the direction of the rail, requiring six different heights of supports. The end of the tunnel was constructed using the open-cut method, and the cross section was even larger than that of the NATM section.

The basic design drawings of the tunnel restoration were included in the bidding documents, and the construction drawings were modified by the same designer after the start of construction to suit the site.

Figure 6-13 NATM Section

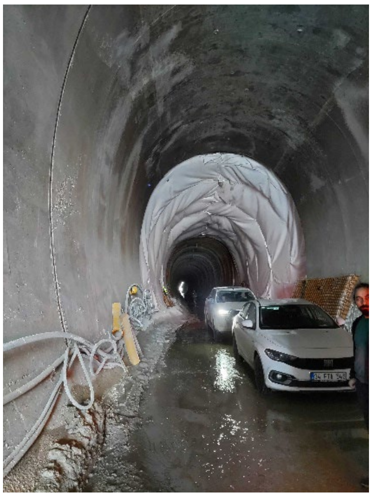
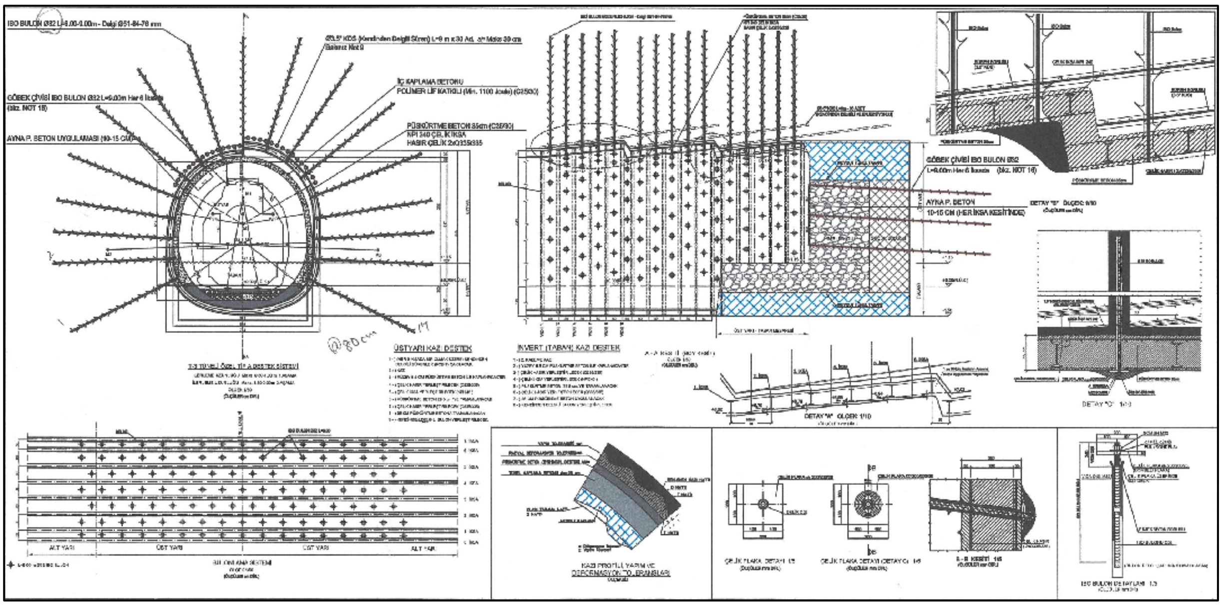


Figure 6-14 Connective Section of NATM and Open-Cut

Figure 6-15 End of Open-Cut Tunnel

Source : JST



Source: TCDD

Figure 6-16 Drawing of NATM Section

c) Alman Bridge

According to the May 2023 survey, there was no track displacement in the track section of the bridge. Some components composing the girders and arch sections were generally in good shape, although there was some separation and falling of the concrete covering. They will be able to withstand service in the future with appropriate maintenance and management.

On the other hand, the damage to unreinforced concrete foundation structure pillar legs was extremely severe. The column legs had wide longitudinal and diagonal cracks at the column heads on the underside of the arch base, and some of the vertical support functions were severely degraded due to the reduction of the support cross-sections as a result of the partial chipping off of the cross-sections.

In some cases, large residual cracks were observed in the column legs of unreinforced sections, although the vertical support function had not yet been compromised. The damage was characterized by minor damage to the face where the foundation of the support structure was installed in the direction of the railway track, and large sectional loss and cracks leading to sectional loss were observed on the face of the column heads in the direction perpendicular to the railway track, indicating a loss of vertical support function.

The bridge was subjected to large horizontal and vertical responses due to the earthquake, and vertical and eccentric axial forces acting on the arch base caused cracks and damage to the tops of the unreinforced foundation structural column legs. However, the RC structure of the column head support foundation suppressed the damage to the track direction, and the vertical support function was maintained to a certain degree, which is presumed to have prevented the collapse of the column.

In all the columns of the arch bridge, especially those with reduced cross-sections, it was obvious that the vertical support function had deteriorated and that the function should be restored as soon as possible. As a permanent measure, it was considered that the best solution would be to reinforce all (6) unreinforced concrete column legs with RC wrapping, as Prof. Dr. Alp suggested in his report. Although this bridge is designated as a cultural asset, permission was granted by the Turkish Cultural Office, and construction could begin soon after the survey in May 2023.

The restoration work was performed using the RC wrapping method, which was a common proposal on both the Turkish and Japanese sides. The concrete was placed by press-in, but cracks were noticeable on the surface.

Since there was no connection between the piers and the superstructure, the survey team had advised the Turkish side to consider how to deal with horizontal displacement of the superstructure at the time of the May 2023 survey, but as a result of the Turkish side's investigation, metal fittings were installed in the RC wrapping.

Source: JST

Figure 6-17 Overall View of the Bridge

Source : before the restoration：May 2023 survey, after the restoration：JST

Figure 6-18 View of Pier C (Left: Before Restoration, Right: After Restoration)

d) Rockfall Prevention Work Using Corrugated Plate Tunnels

Although not surveyed in the May 2023 survey, a large-scale rock-fall protection structure has been constructed at a point about 15 km from the Armand Bridge toward Malatya (Figure 6-19).

Source: JST

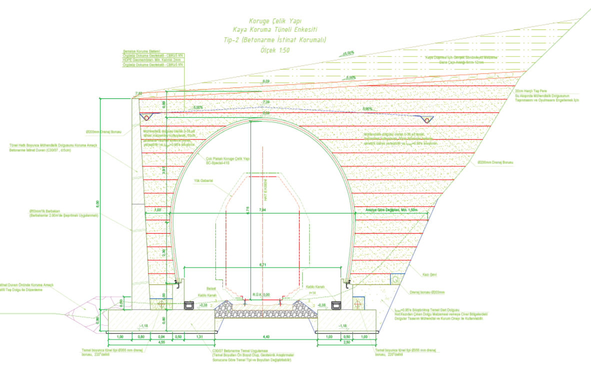
Figure 6-19 Entire View of the Corrugated Tunnel (Around Chainage 160 km)

The structure consists of a RC retaining wall on the valley side, corrugated plates in an arch shape, backfilling around the wall, and casting protective reinforced concrete (t=150mm, soil cover 1.5m, slope 20%) on the upper part. According to a Turkish engineer, 9,000 J of energy is the design value, but we have not been able to examine the details. Corrugated plate tunnels have often been constructed at the intersection of highway embankment structures and ordinary roads, etc. One TCDD line has been using similar rock fall protection for 4 years (Figure 6-20), and its specifications are still in the process of being improved.

Figure 6-21 shows the design drawing used for the 3km section described below. This drawing shows the protective concrete (t=200mm, 5% slope) and the gravel that acts as a buffer, but the gravel is not of a uniform thickness, and the layer thickness increases at a 10% slope towards the mountain side.

Source: TCDD

Figure 6-20 Rock-Fall Prevention Work Using Corrugated Plate Tunnel



Source: TCDD

Figure 6-21 Drawing of Corrugated Plate Tunnel

e) Earth Structure

The cut slope in the 3 km section between Fevzipaşa and Islahiye (hereafter referred to as the 3 km section), which runs southward near the Syrian border, has a geological structure consisting mainly of limestone. On steep slopes of the 3 km section, rock-fall protection structures were constructed to cover the slopes with nets, and on gentle slopes, in addition to nets, fences were installed to prevent the rolling of boulders at various places.

In the embankment section of the 3 km section, the slides occurred toward the valley side, causing cracks and settlement on the embankment shoulder.

Slope collapse was observed in the cut section on the 3 km section. It is considered that the cracks occurred during the process of weathering and fragmentation of the bedrock due to rainfall and melting snow, and that the cracks progressed and the slope collapsed due to large seismic shaking.

In the May 2023 survey, it was assumed that resumption of operation after implementation of permanent countermeasures would take time because of the wide area and large scale of the source of the falling rocks. Therefore, they proposed a method of resuming operation by removing boulders and loose rocks in a hazardous condition as an emergency measure, followed by permanent measures. For permanent measures, they proposed a method that combines not only structural measures but also non-structural measures such as detection and warning devices. However, it was emphasized that the location of the detection devices will require the advanced judgment of engineers on site.

At the time of this survey, no work was in progress except for the removal of the entire track, and a boring survey was in progress. The area along the line is one of the warmest in Türkiye and has a lot of vegetation, and there were many cases of cracks expanding due to plant roots and other factors as well as wind and rain. In such an environment, rock fall is likely to occur regardless of weather conditions, so non-structural measures could be effective.

Figure 6-22 Situation Where Track Has Been Removed From 3 km Section

Figure 6-23 Accelerated Weathering by Plant Roots

Source：JST

Through the exchange of opinions and other opportunities in this survey, it was felt that TCDD engineers have a strong interest in non-structural measures for disasters. In particular, many engineers asked questions about the emergency stop mechanism of trains at every stage of the project.

At the site, there were various types of rock falls depending on the location (Figure 6-23 and Figure 6-246), and they were having trouble selecting countermeasures using structures, mainly box tunnels with RC structures, corrugated tunnels, a method of covering the slope with a net (Figure 6-25), and protective fences. JST asked for provision of the slope management maps that were necessary for the selection of countermeasures in place. The TCDD answered that they have the map, but JST was not able to examine the actual maps.

Figure 6-24 Slope With Many Boulders

The diameter is small, but the frequency of falling rocks is high

Figure 6-25 Rock Fall Prevention Net

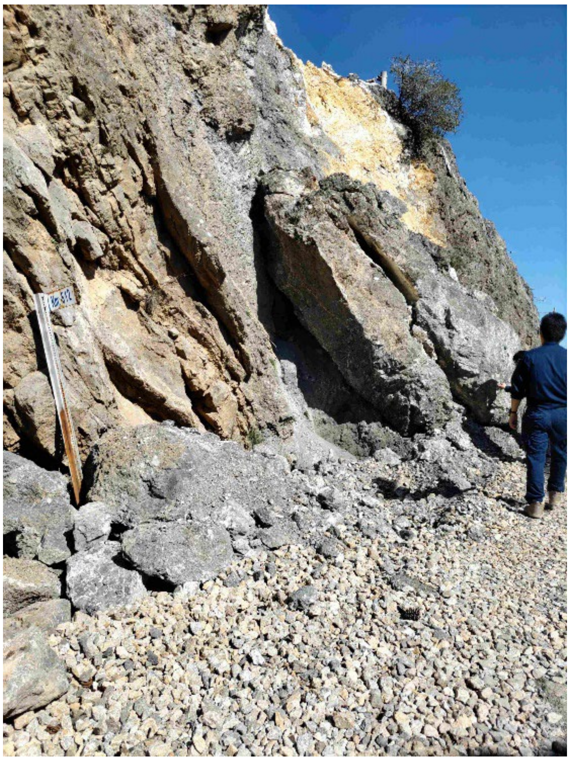


Figure 6-26 Huge Fallen Rocks

Source: JST

f) South Slope of Fevzipaşa Station

At the northern end of the 3 km section, a slope collapse was observed on the southeast-facing slope on the southwest side of the Fevzipaşa Station premises, and it appears that the retaining wall collapsed (Figure 6-27). TCDD reported that this was a major landslide and that there may be deep cracks beneath the slope at Fevzipaşa.

TCDD is considering a design to resist slope collapse by driving piles into the slope, but the site above-mentioned is at the top of a very high slope, and it seems that there are problems with the construction plan.

Figure 6-27 Collapsed Retaining Wall

Figure 6-28 Collapse of Roadbed

Source: JST

Source: TCDD

Figure 6-29 A Photo of the South Side of Fevzipaşa Station Taken Shortly After the Earthquake

g) Steel Bridge

There was also a steel bridge that was not surveyed in this study. There are plans for river improvement in the area, and construction will begin after discussions with the river authorities are concluded.

6.1.5 Construction Issues as of the February 2024 Survey

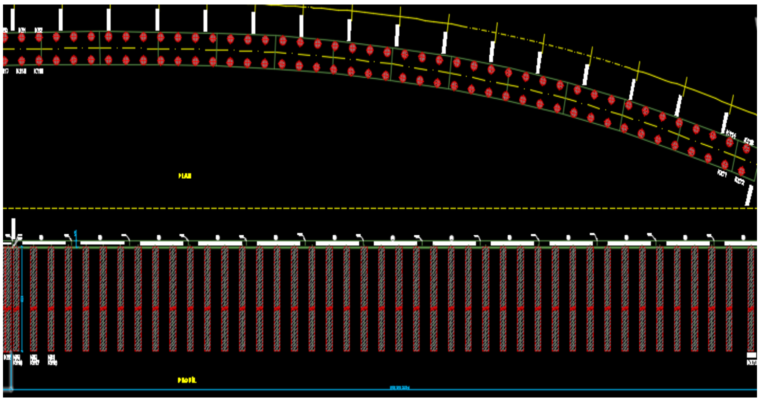
The focus of the construction work has shifted to roadbed improvement work aimed at achieving higher standards and improving safety, and there were no new technical issues that had arisen as a result of the progress of the work since the survey in May 2023.

The issues that TCDD considered to be problems were the collapse of the roadbed from the 3 km section to the Fevzipaşa premises and the restoration of the landslide areas. At the time of the on-site survey for this study, the design had already been completed, but the construction method was still an issue, and there was a possibility that the design would need to be revised based on the results of the construction method study.

Another issue was the evaluation and selection of countermeasures for falling rocks in the 3 km section. TCDD considered that the evaluation and selection of the structure of the rock shed was a particularly important issue among the various types of countermeasures for falling rocks and the state of the geological formation, as the geological formation in the 3 km section had been significantly weathered.

6.1.6 TCDD's Solution to the Construction Issues

Although TCDD did not report to JST on the resolution of the issues with the construction work, JST was able to get an overview of the resolution of the issues from a video released by TCDD.



Source: TCDD

Figure 6-30 Plan for Landslide Prevention at Fevzipaşa Station

Source: TCDD[27]

Figure 6-31 Retaining Wall for Landslide Countermeasures at Fevzipaşa Station

Figure 6-31 shows Fevzipasa Station. The white concrete wall in the middle of the right side of the photo is a retaining wall. TCDD was considering a retaining wall with a pile foundation as a landslide countermeasure. It seems that they carried out the design and construction based on this policy. As the slope on the valley side is high, it seems that small-diameter piles were driven in from the track side using a small pile driver.

Source: TCDD

Figure 6-32 Rockfall Protection Using Corrugated Tunnel

It appears that TCDD adopted corrugated tunnels as the basis for their rockfall protection facilities (Figure 6-32). In the corrugated tunnel shown in Figure 6-32, the valley-side retaining wall seen in Figure 6-21 has not been constructed, and it appears that the backfill material of reinforced soil has been raised. Comparing it with the rockfall protection facility in Figure 6-20, it can be seen that the specifications have been greatly improved. On the mountain side of the rock shed, the surface weathering layer has been removed and flat areas have been set on the slope to absorb the energy of falling rocks as they fall. On the left side of the photo, the rockfall protection retaining wall and ditch work (rockfall pocket) have been constructed, and it appears that the surface weathering layer has been

[27] https://www.facebook.com/tcddemiryollari/videos/projemizin-amac%C4%B1-depremde-hasar-g%C3%B6ren-g%C3%B6lba%C5%9F%C4%B1-malatya-istasyonu-aras%C4%B1nda-bulunan/975048300820753/ (Accessed June 1, 2025)

removed in the same way.

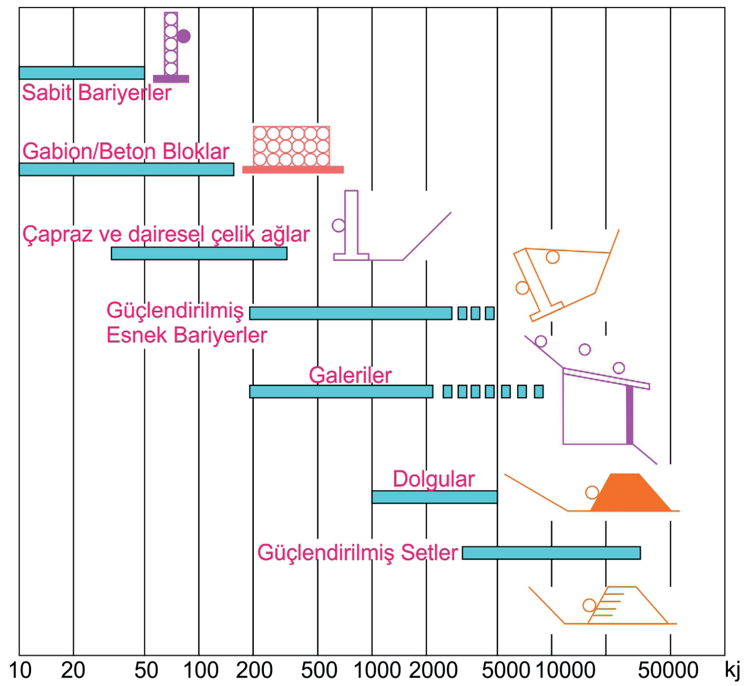
(1) Selection of Rock Fall Protection (Rock Shed) Structure

1) Rockfall Protection Measures in Türkiye

Rockfall is a disaster that occurs frequently in Türkiye. Looking at the number of disasters that led to household relocation from 1950 to 2007, 43% were landslides, 18% were mudslides, and 9% were rock falls. Although the number of households that relocated per incident is thought to be high, it accounts for 13% of the total number of disasters (Ozden et al. 2008). Rockfall disasters can also occur in conjunction with landslides, mudslides, and earthquakes.

It was found that Türkiye's approach to rockfall prevention is based on the same academic system as Japan's, and that there is a shared understanding of research, selection of countermeasures, design and construction, and maintenance and management of rockfall prevention measures, rockfall protection measures, rockfall prevention facilities, and rockfall protection facilities (see “Rockfall Prevention Handbook” (Japan Road Association) and “Technical Guide for Evaluating Disasters Caused by Rockfall” (AFAD)).

In terms of design materials, many design formulas have been devised based on various experiments and simulations, but the scope of application of each design formula is very limited, and the academic system itself for rockfalls is one that should be further studied in the future.



Source: AFAD ” KAYA DÜSMELERINDEN KAYNAKLI AFETLERIN DEGERLENDIRILMESINE YÖNELIK TEKNIK KILAVUZ”

Figure 6-33 Application of Rockfall Protection Methodologies

2) Structure of Rock Sheds Against Falling Rocks

Rock sheds, which are one type of rockfall protection measure, are a common sight in Japan. Rock sheds are built using reinforced concrete or steel structures, and although they are the most expensive and largest-scale of the various countermeasures, they are often adopted in Japan, which has many steep mountainous regions. In Türkiye, on the other hand, the most common method is to use retaining walls and ditches to protect against falling rocks, and this is the most extensive type of countermeasure. The line affected by the earthquake in February 2023 is located in the mountainous region of eastern Türkiye, and rockfall protection measures using rock sheds are being considered for the sections along the valley. The structure uses corrugated steel plates.

3) Arch Tunnel-type Rock Shed Using Corrugated Plates

In Türkiye, corrugated plate arch culverts (corrugated plate tunnels) are often constructed at the intersection of highways and high-speed railways with embankment structures, as well as at roads and rivers. Corrugated plate arches can be assembled from small parts on site, mainly by hand, and the components are easy to bring to the site. There are also many advantages, such as the fact that large heavy machinery is not required, and construction can be completed in a short period of time. In particular, in this case, it is excellent for construction in narrow railway tracks in mountainous areas.

However, the corrugated steel plate itself has low load-bearing capacity, and it cannot be used as a structure in the absence of adequate surrounding soil pressure or ground reaction force. By ensuring that the surrounding area is backfilled, the corrugated plate arch culvert becomes a rational structure that can withstand very large loads.

TCDD has adopted corrugated plate arch rock sheds as a rockfall protection structure (Figure 6-20). A corrugated arch rock-shed has been constructed between Karabük and Zonguldak. It was constructed in 2019, and there have been no major rockfalls since then, but the gravel at the top, which acts as a buffer, has been washed away by water flow, and gravel has spilled into the tunnel (Figure 6-34, Figure 6-35). The biggest problem is the lack of adequate surrounding soil pressure and ground springs, and even a small rockfall could cause significant deformation. In the design of the restoration work this time, a reverse L-shaped retaining wall or earth retaining wall was placed on the valley side of the rockfall protection structure. Since it was impossible to obtain the design calculation sheet for the corrugated plate arch culvert from TCDD, a simple framework analysis was used to perform a simple investigation of the deformation of the structure and the energy of the rockfall.

Figure 6-34 Gravel on Top of Corrugated Plate Tunnel Rock-Shelter Were Washed Away

Figure 6-35 Gravel has spilled into the tunnel

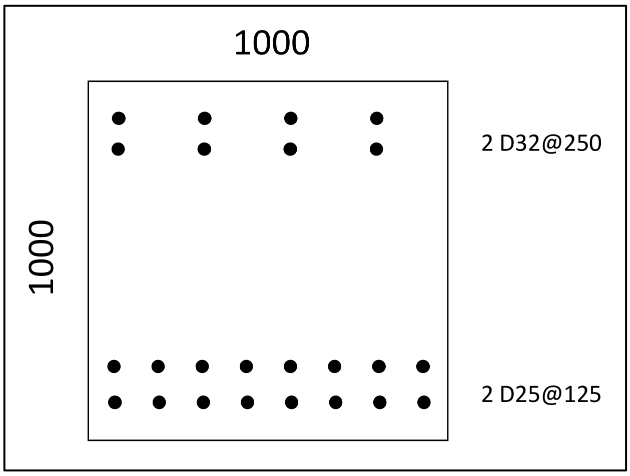
Source: JST

4) Comparison of Rock-Shed Structures

The deformation of rock-shelter structures due to falling rock energy was compared for RC boxes and corrugated plate arches. As the number of cases using a three-layer buffer structure with EPS is increasing, it was also added to the cases examined. An explanation of the structures and load cases assumed for the study are given below.

・ Cross-section of RC box

Figure 6-36 shows the cross-section of the top slab of an RC box. The height of the members of the top slab, walls and bottom slab was set at 1 m, and the reinforcement was arranged as shown in Table 6-3. The yield point of the reinforcement was assumed to be the yield bending moment of the member (M_y), and the ultimate bending moment was also assumed to be the same (underestimation).



Source JST

Figure 6-36 Cross-Section per 1 m of the Top Slab of the RC Box

Table 6-3 Cross-Sectional Dimensions of RC Box

	Top Slab	Wall	Bottom Slab
Tension rebar	2 D25−125	2 D25−250	2 D25−250
Compression rebar	2 D32−250	2 D16−250	2 D16−250
Effective height	0.85	0.85	0.85
Yield strength of rebar MN/m2	345	345	345
Concrete strength MN/m2	24	24	24
M_y kN･m	1992	1649	1029

Source: JST

・ Cross-section of corrugated steel plate

The cross-section of the corrugated steel plate is shown in Figure 6-37. The corrugated plate is assumed to have a thickness of 8 mm and a member height of 150 mm. The material was unknown, so it was assumed to be equivalent to SS330 in Japanese standards.

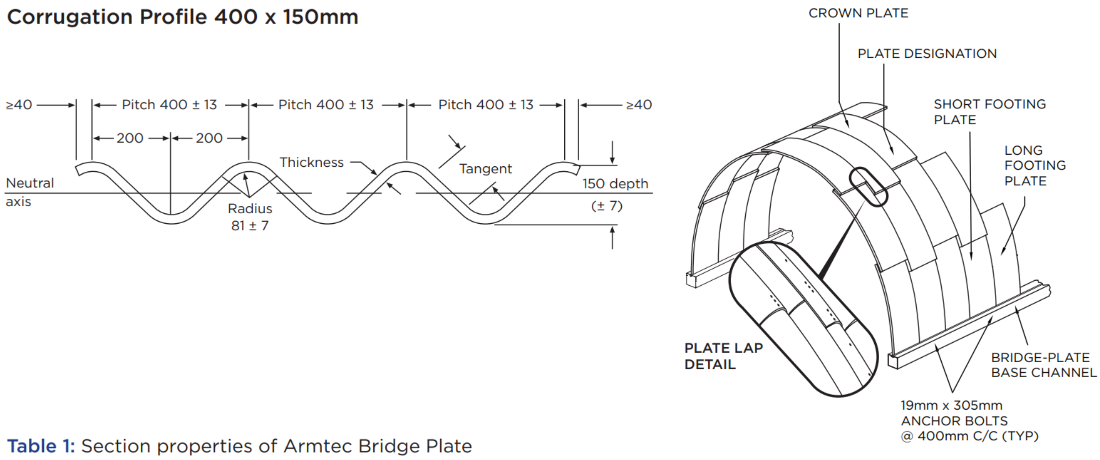


Table 1: Section properties of Armtec Bridge Plate

Nominal Thickness (mm)	Design Thickness (mm)	Tangent Length (mm)	Angle θ (degrees)	Area of Section (mm^2/mm)	Moment of Inertia (mm^4/mm)	Elastic Section Modulus (mm^3/mm)	Plastic Section Modulus (mm^3/mm)	Radius of Gyration (mm)
4.3	4.21	112.41	51.29	5.792	16,187	200.52	273.62	52.86
5.0	4.95	111.42	51.44	6.811	19,060	235.04	321.70	52.90
6.0	6.00	110.00	51.64	8.260	23,154	283.71	390.57	52.95
7.0	7.00	108.63	51.84	9.640	27,071	329.69	456.35	52.99
8.0	7.94	107.33	52.03	10.940	30,759	372.48	518.88	53.04

Source: armetec Bridge Plate

Figure 6-37 Cross-Section of the Corrugated Steel Plate

・Corrugated Steel Plates

Type 1 corrugated sections of corrugated pipes are equivalent to or better than SPHC in JIS G 3131, and Type 2 are SS330 in JIS G 3101.

Table 6-4 Corrugated Steel Plates: Mechanical Properties

Material	Chemical composition %		Mechanical properties			
	P	S	Yield point	Tensile strength	Extension %	Bending angle
SPHC	0.050≧	0.050≧	―	270N/mm2≦	29≦ (1.6≦t<3.2mm) 31=< (t≧3.2mm)	180°
SS330	0.050≧	0.050≧	205N/mm2≦	330 to 430N/mm2	26=< (t≦5.0mm) 21≦ (5.0<t≦16mm)	180°

Source: JFE Corrugate Board Product Pamphlet

・ Impact force and energy of falling rocks

The impact force of falling rocks is given by the following formula.

$$P=2.108\cdot(m\cdot g)^{2/3}\cdot\lambda^{2/5}\cdot H'^{3/5}\cdot\alpha$$

P : Impact force of falling rock (kN)

m : Mass of falling rock (t)

g : Acceleration of gravity (m/s^2)

λ: Lame's constant (kN/m^2) H' : Height of falling rock (m)

α : Coefficient determined by the ratio of the thickness of the sand layer to the diameter of the falling rock

$\alpha=\sqrt{(D/T)}$ When $T\geq D$, $\alpha=1.0$

D : Diameter of falling rock (m) T : Thickness of sand layer (T>0.9m)

Table 6-5 Bending Moment of Corrugated Steel Plate

Yield bending moment	M_y	84	(kN·m/m)
Ultimate bending moment	M_u	135	(kN·m/m)

Although the AFAD technical materials do not show the impact force on a rock shed, the same formula is shown as the impact force on a rockfall protection retaining wall (Yoshida 2007). (The difference in the first coefficient is due to the fact that the mass of the rockfall is expressed in kg).

$$F=0.02(m.g)^{0.67}\lambda^{0.4}H^{0.6}\left(\frac{T}{D}\right)^{-0.58}$$

（Yoshida, H., Nomura, T., Wyllie, D. C., Morris, A. J. (2007) Rock fall sheds–application of Japanese designs in North America. Proc. 1st. North American Landslide Conference, Vail, CO., AEG Special Publication No. 22., ed. Turner, A. K., Schuster, R. L., pp. 179-196.）

The energy is E = mgH'. In this trial calculation, H' was set to a constant (50 m) and the diameter of the falling rocks was changed to set up the following cases (Table 6-6).

Table 6-6 Pattern of Energy of Falling Rocks Used in the Trial Calculation

	D (m)	mg (kN)	H' (m)	λ (kN/m2)	T (m)	α	P (kN)	E (kJ)
1	0.45	1.24	50	1000	1	1	403	62
2	0.8	6.97	50	1000	0.5	1.26	1,612	349
3	1	13.61	50	1000	1	1	1,992	681
4	1	13.61	50	1000	0.5	1.41	2,817	681
5	1	13.61	50	(EPS 0.5m)			1,860	681
6	1.2	23.52	50	1000	1	1.10	3,142	1,176
7	1.2	23.52	50	1000	0.5	1.55	4,443	1,176
8	1.2	23.52	50	(EPS 0.5m)			2,056	1,176
9	1.5	45.95	50	1000	1	1.22	5,489	2,297
10	1.5	45.95	50	(EPS 0.8m)			2,169	2,297

Source: JST

The falling rocks were assumed to fall at an angle of 60°, and the horizontal load was also taken into account. The loading point was set at the center of the target structure, and the trend was examined by analyzing only the direction perpendicular to the railway track (Figure 6-38).

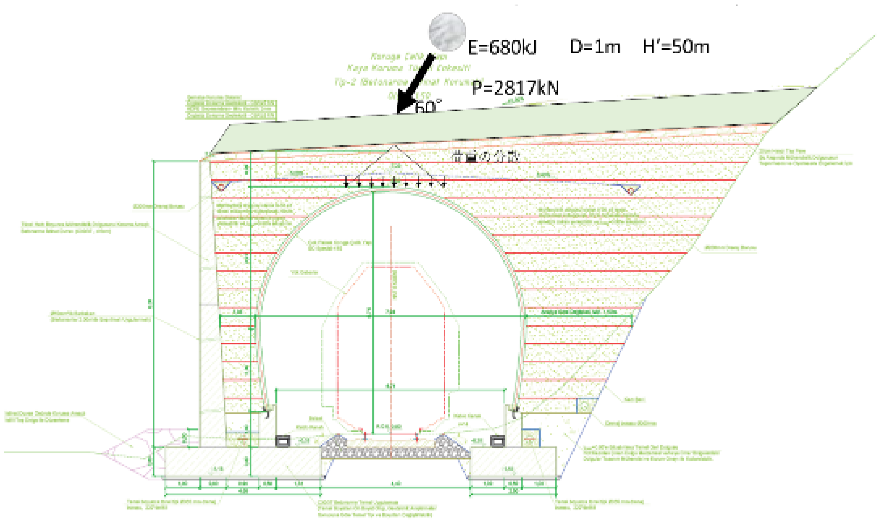


Figure 6-38 Simulation of Rockfall Energy and Structural Deformation

Source：JST added to TCDD's drawing

・ Trial calculation using frame analysis

a.) Corrugated plate arch only (Figure 6-39)

In actual corrugated plate arch tunnels, the arch is covered with crushed stone, but this model does not take crushed stone into account. Corrugated plate arch tunnel yields under a small load and produces huge displacement (deformation). In the case of no crushed stone at all, a 0.5m diameter rockfall from a height of 50m (with an energy of around 62 kJ) would cause a displacement of 70mm and reach the ultimate bending moment (Figure 6-44).

b.) Case where the arch is subjected to earth pressure and ground reaction force from both sides (Figure 6-40)

This is the case where the track is at the bottom of a valley and forms a complete tunnel. This is a situation that makes the most of the characteristics of corrugated arch culverts. Backfill soil (thickness 0.8m) is placed on top of the corrugated arch, and on top of that is a concrete drainage layer (thickness 0.20m) and a buffer material of sand (1m). It was thought that the load would be dispersed from the bottom of the buffer material sand and transmitted to the arch culvert. It was also thought that a 1.2m diameter falling rock would cause compressive stress to exceed the limit, resulting in excessive displacement (Figure 6-44).

c.) RC box (Figure 6-41)

In many cases, the valley side is usually made into a pillar, but we considered that pillars with the same rigidity as the walls would be placed there. The pillar spacing is often around 4m, so we calculated the width using a member of 4m (we calculated the member of 1m with the load set to 1/4). The main reinforcement in the member is set to two levels, and the ratio of tensile reinforcement in the top plate is set to around 1%, which is thought to be the upper limit. A 1.2m diameter falling rock absorbs 1200kJ of energy at a displacement of 6mm. At 1800kJ, the yield bending moment is reached, and the displacement is about 8mm. If we assume that twice the displacement at yield absorbs three times the energy at yield, it is possible to absorb a relatively large amount of energy of about 5000kJ. With a displacement of around 25mm, which is three times the displacement at yield, it is expected that 8000kJ of energy will be absorbed, but large-scale repairs will be necessary.

d.) Corrugated plate tunnel rock shed with retaining wall on valley side (Figure 6-42)

This is a type with a retaining wall on the valley side to prevent deformation. In the trial calculation, the maximum soil pressure on the retaining wall side was set at 1/3 of that on the mountain side, and the ground spring was set at 1/10. Compared to b), there is a possibility of 3 times the displacement for the same energy. It yields at around 700kJ and excessive displacement deformation occurs. Also, if the retaining wall is damaged by falling rocks, etc., there is a risk that it will rapidly approach the case of a), and it is dangerous if falling rocks occur continuously.

e.) Corrugated plate arch tunnel rock shed with a retaining wall on the valley side and three-layer buffer material (Figure 6-43)

The three-layer buffer structure consists of three layers: sand for the surface layer, RC slabs for the core layer, and EPS for the back layer. The sand in the surface layer prevents direct damage to the RC slabs, while the EPS serves to disperse the impact force over time. Calculating the impact force using the three-layer buffer structure is a combination of various formulae with various limitations, and the range of the

verified results is also limited, but experiments have shown that it is highly effective. The distribution of the load using the three-layer buffer structure is said to be 3m x 3m. In this case, the distribution was further expanded (4m x 4m) by adding a 0.5m fill layer. According to the impact force calculation method in the Rockfall Prevention Handbook, there is almost no increase in impact force due to the increase in rockfall energy, but the energy does require an increase in the thickness of the RC plate and EPS layer. It must also be said that the range of the verification experiment is up to 2000kJ, which is a shortcoming in the design.
In Case d), it was only able to withstand a falling rock energy of around 700 kJ, but with the three-layer buffer material, it will be possible to handle a falling rock energy of up to 2000 kJ, so it is thought that there will be significant benefits in applying it to the corrugated arch rock sheds currently under construction (Figure 6-44).

・ Summary of Comparison
JST attempted to compare corrugated plate arch tunnel rock sheds with RC rock sheds. The RC rock shed in c) can be adjusted to withstand the expected falling rocks by changing the thickness of the components and the amount of steel reinforcement, and it is also possible to withstand up to 10,000 kJ of energy, as shown in Figure 6-44. On the other hand, corrugated plate arch tunnel rock sheds can only withstand a maximum of 1,000kJ of falling rock energy, which is 1/10 of that of RC tunnel type rock sheds, and there is also a possibility that the rock shed will suddenly deform greatly.
The section between Iskenderun and Malatya is an electrified section, and TCDD has designed the overhead line equipment to be attached directly to corrugated steel plates. The survey team pointed out the dangers of attaching the overhead line equipment directly to corrugated steel plates during the on-site survey, but the TCDD side felt that there was little need to revise the plan. It can be seen that in the case of using three layers of buffer material (e), it is possible to greatly reduce the input of rockfall energy. If the assumed energy is large, it is necessary to increase the thickness of the EPS, but in electrified sections, it may be necessary to add a measure to reduce the energy of falling rocks using three-layer buffer material, especially in corrugated arch rock sheds. In addition, for falling rocks with energy exceeding the applicable range (2000kJ), it is necessary to continue implementing falling rock prevention measures such as removal and rooting, and falling rock protection measures such as falling rock protection nets and fences.

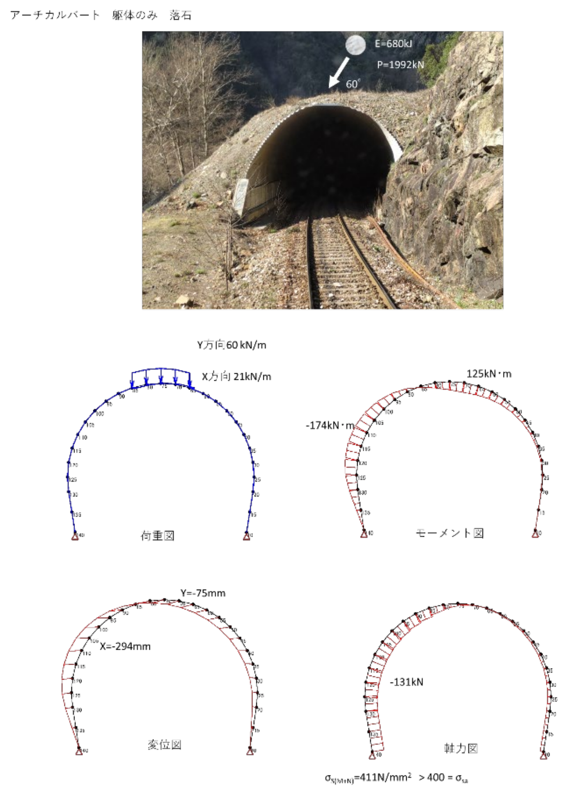


Figure 6-39 Corrugated Plate Arch Only

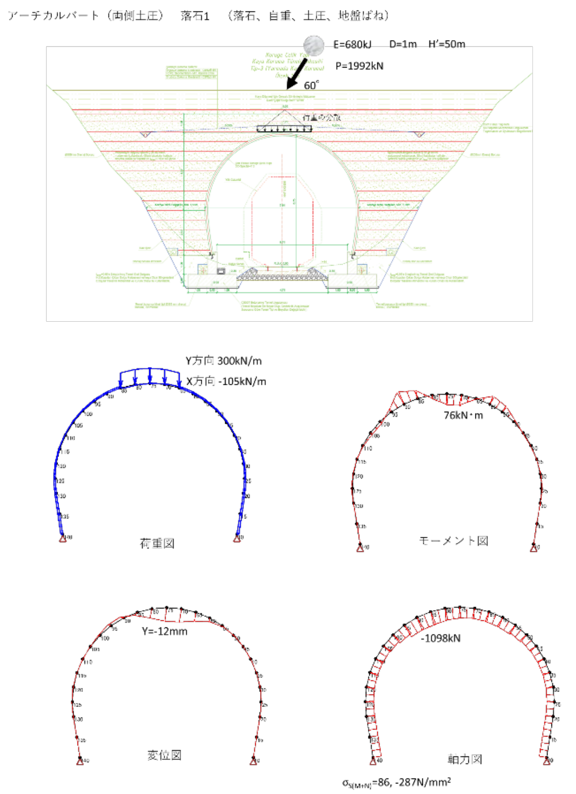


Figure 6-40 Case Where the Arch is Subjected to Earth Pressure and Ground Reaction Force From Both Sides

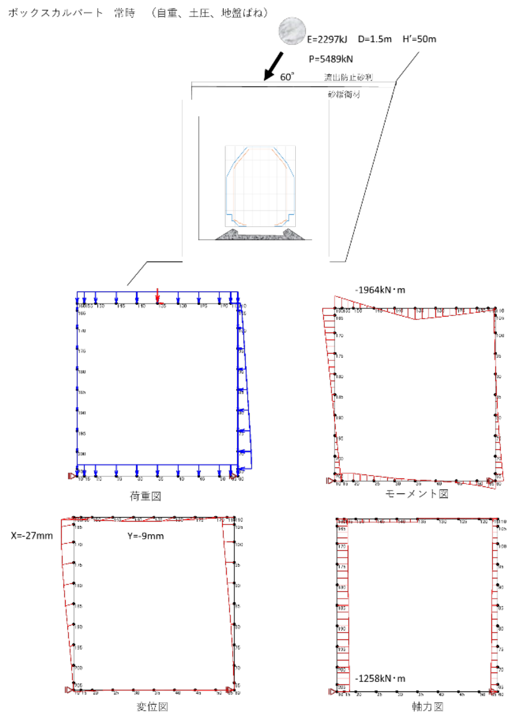


Figure 6-41 RC Box

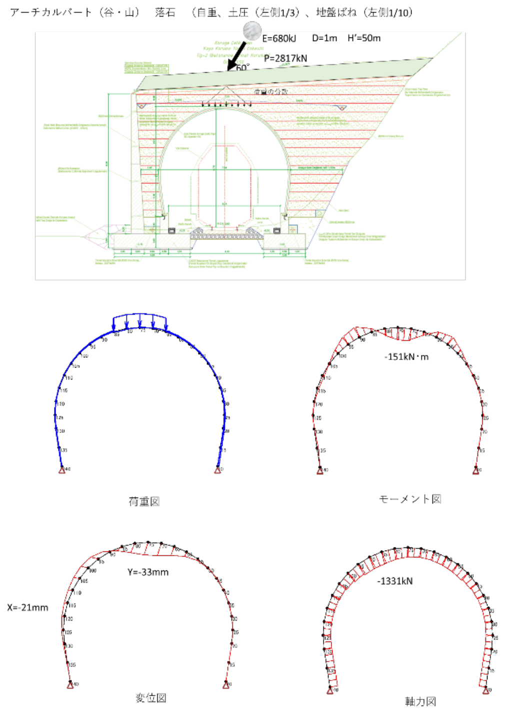


Figure 6-42 Corrugated Plate Tunnel Rock-Shelter With Retaining Wall on Valley Side

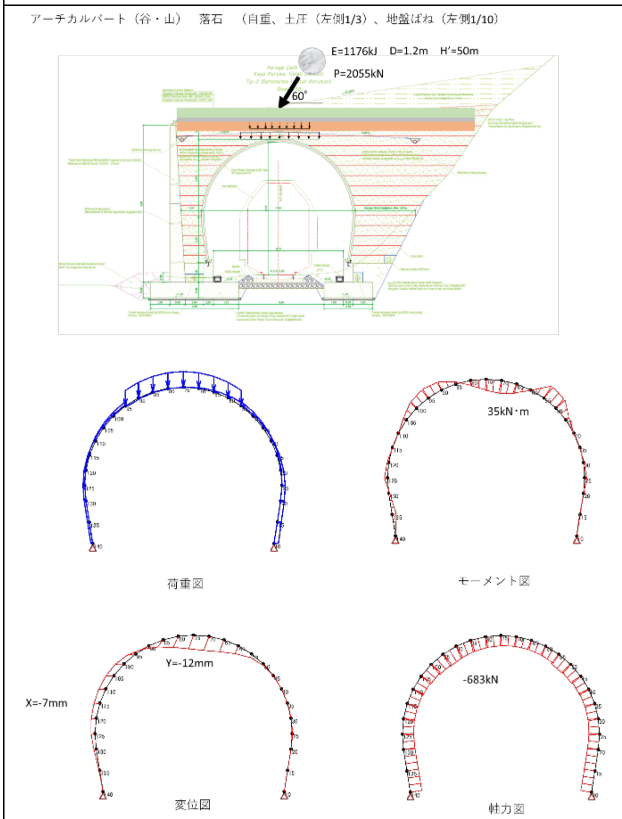
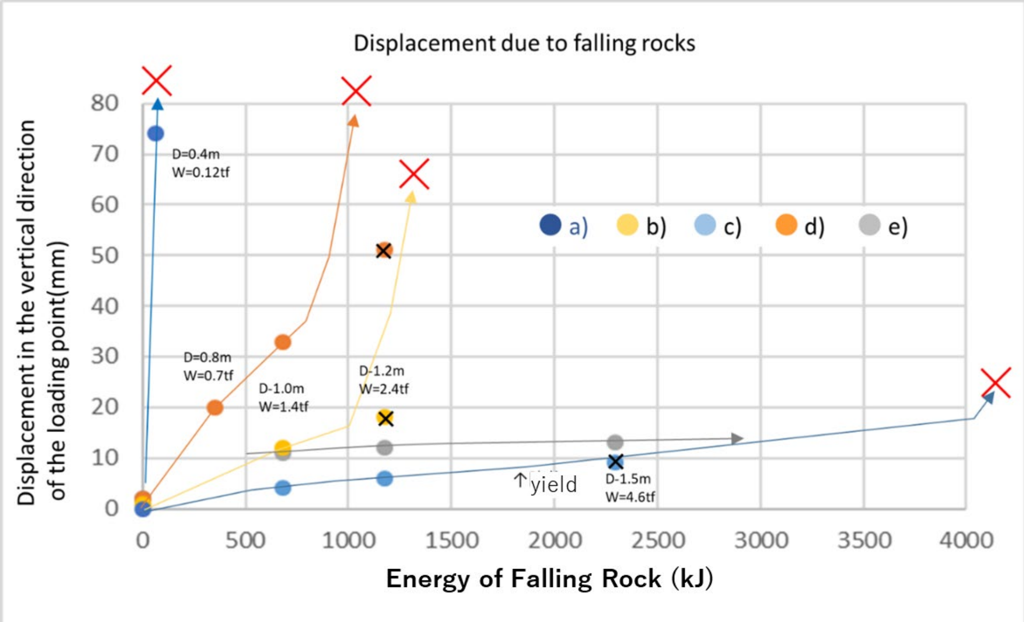


Figure 6-43 Corrugated Plate Arch Tunnel Rock Shed With a Retaining Wall on the Valley Side and Three-Layer Buffer Material

Source: JST



Source: JST

Figure 6-44 Displacement of Structures Due to Falling Rocks

・ Construction of corrugated plate tunnel rockfall protection

According to the TCDD video, the construction of the corrugated steel sheet tunnel appears to be in accordance with the plans, but the distance to the valley side retaining wall appears to be larger than the design (Figure 6-45). Figure 6-46 shows the construction in progress.

Source: TCDD

Figure 6-45 Completed Corrugated Tunnel

Source: TCDD

Figure 6-46 Corrugated Tunnel Under Construction

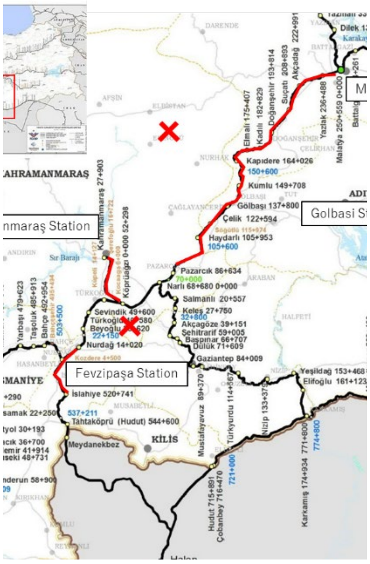
6.2 Issues in the Disaster Restoration System

6.2.1 Initial Response

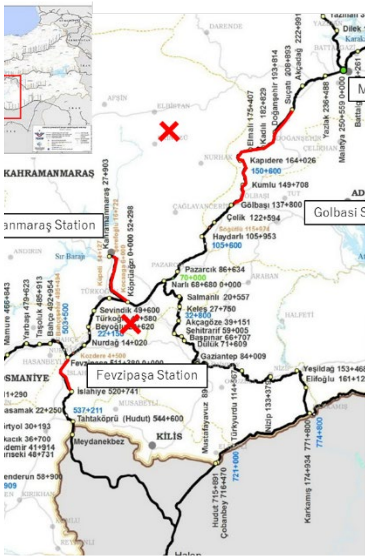
TCDD's line length in the affected area is 1,275 km, and TCDD began on-site investigations immediately after the earthquake. During on-site investigation interviews, we learned that TCDD employees began on-site investigations two days after the earthquake.

TCDD took restoration measures such as repairing the tracks, and after one week, they confirmed that 1,060 km of the tracks were in a state where trains or vehicles could run on them, or that the tracks were in a state where they could be run on (excluding electrified section train line equipment and signal equipment). At this point, the sections that were out of service were Islahiye-Fevzipasa (9 km), Fevzipasa -Nurdağ (14 km), Köprüağzı-Kahramanmaraş (28 km), and Pazarcık-Malatya (164 km), totaling 215 km (Figure 6-47). Two weeks after the disaster, the sections that were out of service were Islahiye- Fevzipasa (9 km), Köprüağzı -Kahramanmaraş (28 km), and Gölbaşı-Suçatı (71 km), leaving a total of 108 km of out-of-service sections. By the time of the May 2023 survey[28], trains were able to run on the entire section except for the area of the structures inspected in the survey. Since most of the affected sections had an earthen roadbed, it was thought that restoration would have been easy.

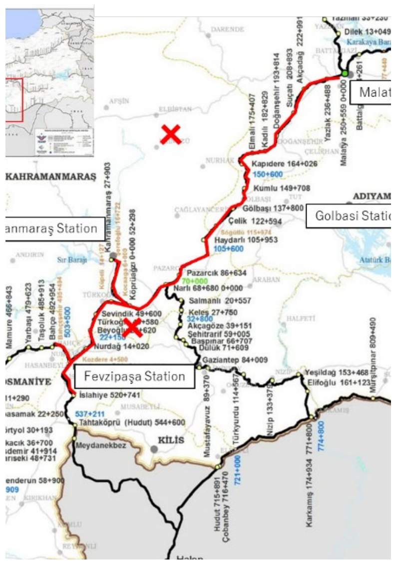
[28] According to Turkish media (Milliet Web Article and other articles)



Sections closed one week after the earthquake



Sections closed two weeks after the earthquake



Sections currently closed due to earthquake restoration work (Currently)

Source：JST added lines on TCDD data.

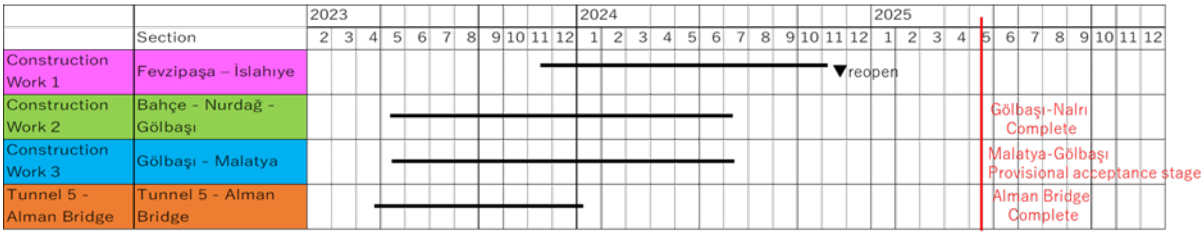
Figure 6-47 Changes in the Number of Sections That are Out of Service After the Earthquake

As it took time for roads to be restored, the railway contributed to the transportation of disaster victims and fuel and other supplies, and TCDD also worked in cooperation with AFAD to provide relief to disaster victims, including housing them in buildings and vehicles owned by TCDD.

In Turkey, restoration work begins after the budget has been prepared. For this reason, it appears that in some cases, roads and other infrastructure are reopened while assessing the damage to structures in order to provide emergency logistics support to disaster-affected areas. In Japan, structures are selected based on the importance of railway and road routes from the perspective of urban life and logistics support, and emergency restoration is carried out. Routes and structures that are not considered important are not included in the emergency restoration phase and are instead restored during the subsequent full restoration phase.

6.2.2 Details of Long-Term Restoration Work

TCDD has been contracted for four long-term civil restoration works, three of which are divided according to the section of the line, and one of which is dedicated to the Alman Bridge and No. 3 Tunnel (Figure 6-48, Figure 6-49).



Source：JST

Figure 6-48 Contract Package and Construction Schedule for Restoration Work

Table 6-7 Contract for Restoration Works

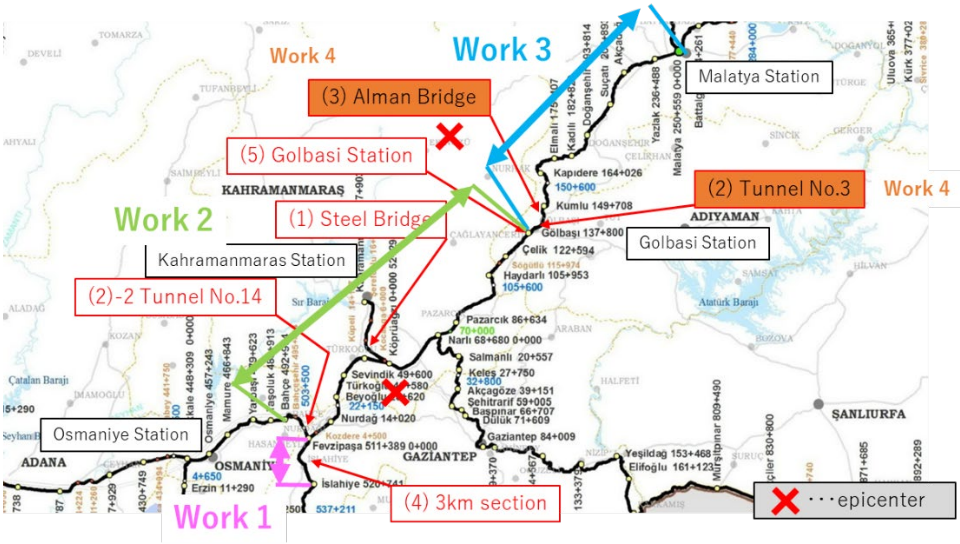
Fevzipaşa-İslahıye Railway Section	
Contractor Name	Deha Altyapı A.Ş.
Date of Contract	14.11.2023
Contract Price	298,M TL
Site delivery date	27.11.2023
Duration of The Work	360days
Expected End Date	8.11.2024
Bahçe-Nurdağ-Gölbaşı Railway Section	
Contractor Name	Timaş Grup İnşaat A.Ş. Pakyoi İnşaat Taahhüt ve Tic, A. Ş. İş Ortaklığı
Date of Contract	8.5.2023
Contract Price	2,772MTL
Site delivery date	10.5.2023
Duration of The Work	420days
Expected End Date	3.7.2024
Tunnel 5-Alman Bridge	
Contractor Name	Duygu Taahhüt ve Duygu İnşaat A.Ş.
Date of Contract	28.4.2023
Contract Price	327MTL
Site delivery date	28.4.2023
Duration of The Work	247days
Expected End Date	30.12.2023
Gölbası – Malatya Railway Section	
Contractor Name	YSE Yap Sanayive ve Ticaret A.Ş.
Date of Contract	8.5.2023
Contract Price	2,778MTL
Site delivery date	10.5.2023
Duration of The Work	420days
Expected End Date	3.7.2024

Source JST

Table 6-8 Details of Work on the Gölbasi-Malatya Section

Object	Details of the work
Superstructure	68 km of track bed, 170,000 m3 of ballast, ballast-less track, 16 sets of turnouts
Substructure	18km of work roads, 1.3 million m3 of excavation, 40km of ground improvement, concrete retaining walls
Culverts	497 locations

Source JST



Source: JST adds work divisions to TCDD documents

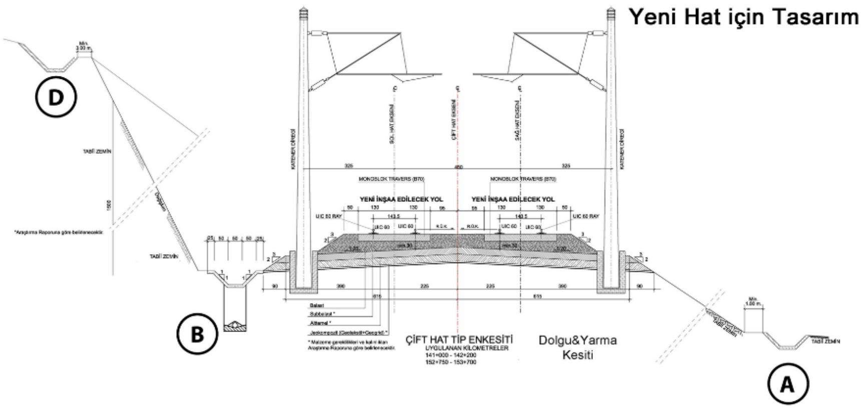
Figure 6-49 Work Division for Restoration Work

TCDD is suspending operations on the Fevzipaşa-Malatya section for construction work. This is because freight trains need to operate along the entire line, and there is no advantage to operating only part of the line. On older TCDD lines, there may be no written standards for buildings and structures, but when restoring them, it is necessary to comply with UIC and EN standards. Due to these circumstances, restoration work on lines built in earlier years will involve upgrading to higher standards (Figure 6-50). One of the aims is to improve the track structure and prepare for high-speed operation when the line is restored.

Construction of Tunnel No. 3 and Alman Bridge began in April 2023, and the deadline for completion was December 2023, but construction was still ongoing as of February 2024. According to the contractor, the reinforcement work on Alman Bridge was completed in July, and the tunnel construction was progressing smoothly.

Construction of the Fevzijpaşa-Gölbaşı section and the Gölbaşı-Malatya section both began in May 2023. The contractor for the latter section said that the winter of 2023-24 was favorable with little snow and good weather, but it seemed difficult to complete the entire construction by the deadline. The mountainous area seemed to pose a bottleneck in the transportation of materials. Construction of the Fevzijpaşa-İslahiye section began in December 2023, with a completion deadline of November 2024. No decision has been made on the structure of the rock fall countermeasures, and design work has not

progressed. In construction projects other than the Alman Bridge section, most of the work involves reconstruction and improvement of the roadbed and construction of rock fall prevention measures.
The track work and electrical work were ordered separately, and the civil engineering contractor was not informed of the progress after the civil engineering work, and his only concern was to complete his own work within the construction period. As the track and electrical work seemed to be progressing at the starting point, it seems that even within TCDD there is little interest in the construction of other systems.



Source TCDD

Figure 6-50 Typical Track Work

As of February 2025, the restoration work on the line between Iskenderun and Malatya was 95% complete[29], but the work between Gökbaşı and Malatya was more than eight months behind schedule. According to media reports, railway operations are supposed to resume on the Gökbaşı line by the end of May 2025. The report on earthquake recovery work[30]states that the financial plan for related works will continue until 2029, but the remaining work mainly involves upgrading signaling systems.
According to information from TCDD as of May 2025, operations between İslahiye and Fevzipaşa resumed in November 2024, construction between Narlı and Gölbaşı has been completed, and the handover from the construction company to TCDD has been completed between Gölbaşı and Malatya.

6.2.3 Issues With Restoration Works After the Earthquake

It can be said that the restoration of railways in many sections following the recent earthquake in February 2023 was quick. This is because many structures are ballasted tracks with soil roadbeds, so there was little need to decide on special policies and there was no need to establish a restoration system. The collapse of the roadbed in Tunnel No. 3, the Alman Bridge, and the Fevzipasa premises are overshadowed by other improvement projects and are taking time to restore. As such, they do not get much public attention. As the number of viaducts, bridges, and large-scale earth structures increases due to improvements to high-speed railways and conventional lines in the future, it will be necessary to

29 https://www.aa.com.tr/tr/gundem/depremlerde-hasar-goren-golbasindaki-demir-yolu-hattinin-onariminda-sona-gelindi/3465189

30 https://www.sbb.gov.tr/wp-content/uploads/2025/02/Kahramanmaras-ve-Hatay-Depremleri-Yeniden-Imar-ve-Gelisme-Raporu.pdf

restore structures quickly, establish emergency restoration techniques, and decide on policies quickly.

6.2.4 Restoration System in Japan

TCDD and JST exchanged information and opinions. JST introduced Japan's technology and system for natural disaster countermeasures, and TCDD introduced the current state of earthquake restoration work and measures for other disasters. In this regard, JR East's earthquake restoration system, seismic reinforcement technology, and seismic design were explained, and the situation in Türkiye was understood in comparison.

JR East's railway structures have suffered significant damage from earthquakes for a long time. In recent years, there have been the 2004 Niigata Chuetsu earthquake, the 2011 Tohoku Pacific Ocean earthquake, and the 2022 Fukushima offshore earthquake. In particular, the 2011 Tohoku Pacific Ocean earthquake caused damage to a wide range of structures from Tohoku to Kanto, but thanks to the establishment of a restoration system and accumulated technical capabilities, the Shinkansen and other lines resumed operation in a short period of time.

1. Overview of Earthquake Damage to High Speed Railways in Japan

● Earthquakes

① The 1995 Southern Hyogo PrefectureEarthquake

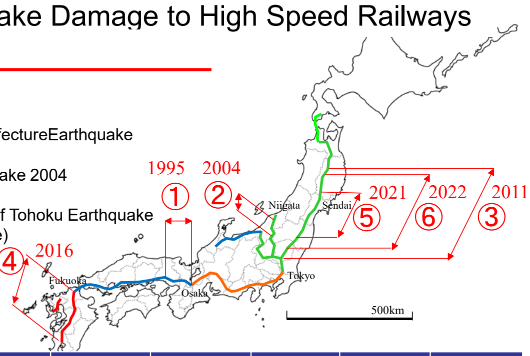
② Mid Niigata Prefecture Earthquake 2004

③ The 2011 off the pacific coast of Tohoku Earthquake (Great East Japan Earthquake)

④ 2016 Kumamoto Earthquake

⑤ 2021 Fukushima Earthquake

⑥ 2022 Fukushima Earthquake



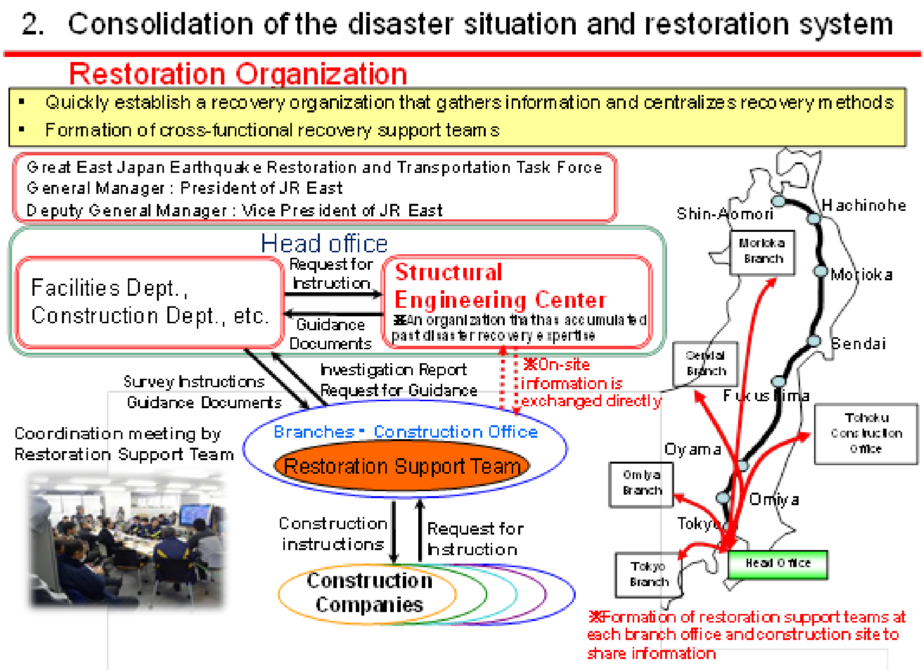
	①	②	③ Main	③ After-shock	④	⑤	⑥
	1995.1	2004	2011.3	2011.4	2016.4	2021.2	2022.3
Magnitude	M 7.3	M 6.8	M 9.0	M 7.1	M7.3	M7.3	M7.4
Seismic Intensity	7	7	7	6+	7	6+	6+
Distance	83 km	56 km	496 km		257km	228 km	344 km
Viaduct	708	47	100	20	37	70	60
Electric pole	43	61	1010	470	0	20	90
Recovery days	81	66	49		13	11	29

Source: JST

Figure 6-51 Earthquake Restoration Record of Japan's Shinkansen Trains

Japan's Shinkansen is an important form of transportation, and JR companies have a strong sense of mission to resume operation in a short period of time. The major earthquake that affected Shinkansen trains since the privatization of the Japanese National Railways was the 1995 Hyogo-ken Nanbu Earthquake, which caused major damage to viaducts, but by reusing viaduct slabs and other forms of ingenuity, operations resumed in three months. Based on this knowledge, measures to reduce damage have been implemented in parallel with technological developments such as seismic reinforcement. In addition, by establishing a structure restoration support system at the Earthquake Disaster Response Headquarters, operations were resumed in an extremely short period of time through efforts such as early start of restoration work by establishing a structure restoration support system.

When a large earthquake occurs in the JR East area, employees and employees of partner companies begin investigating and inspecting facilities while simultaneously confirming the safety of employees. Investigations and inspections are carried out under the direction of the local response headquarters set up at branch offices and construction offices in the affected area. The collected information is sent from the local response headquarters to the relevant departments at the head office in a centralized manner. Since railways are managed by many organizations and systems working together, centralized management of information is necessary. The local response headquarters is responsible for information management and command at the site, and the head office, which is responsible for management, compiles information from related organizations and issues instructions (Figure 6-52).



Source: JR East

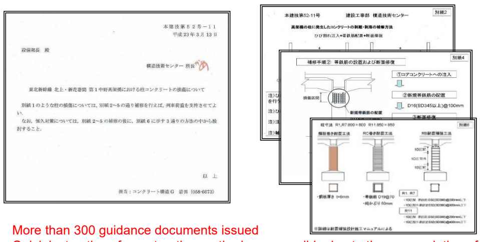
Figure 6-52 JR East's Restoration System

To ensure rapid restoration, the role of a technical support organization is important, as it formulates a restoration policy proposal that is in line with information from the affected site and the restoration process. At JR East, the Structural Engineering Center plays that role. In the event of a major earthquake, once a report of the damage situation is received, a restoration policy is issued as a guidance document within 24 hours (Figure 6-53).

2. Consolidation of the disaster situation and restoration system

Restoration utilizing experiences in past earthquake restoration

Guidance documents were issued **within 24 hours**, allowing for quick repairs.



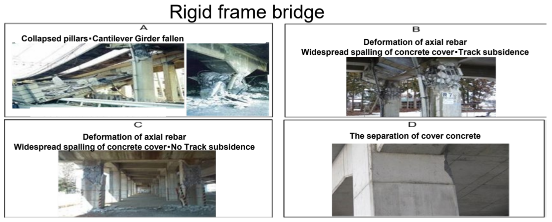
- More than 300 guidance documents issued
- Quick instructions for restoration methods are possible due to the accumulation of guidance documents from past earthquakes

Figure 6-53 Example of Instruction Document

2. Consolidation of the disaster situation and restoration system

Judgement of earthquake damage

Rigid frame bridge



Damage Classification	A	B	C	D	E
Estimated availability of operating trains	Unable to operate	Unable to operate	Possible by slowing down operating speed	Possible	Operational
Estimated restoration time for structures	More than one month	Less than one month	About 3 days	―――	―――
Rigid frame bridge	The bridge has fallen due to the pillars have completely collapsed.	Damage to pillars has caused track subsidence that requires jacking up.	Pillars has damaged, but no track subsidence	Flaking of cover concrete and cracks in the frame	Undamaged

Figure 6-54 JR East Investigation and Inspection Materials

Source: Structural Engineering Center, JR East

TCDD asked about the composition of the technical support organization. As TCDD does not have an organization equivalent to a Structural Engineering Center, they seemed impressed when we replied that the Structural Engineering Center is made up of JR East employees.

They were also interested in the fact that it enables investigators to report the extent of damage using common standards during investigations and inspections (Figure 6-54). They said that Türkiye currently does not possess this capability.

6.2.5 Proposals for the Restoration System

a.) Accumulation of experience and technical skills backed by experience

It is necessary to establish an organization with high technical skills, such as the Structural Engineering Center of JR East, and to accumulate experience in responding to disasters.

As the decisions of the professors at the Turkish universities and the engineers at JR East were mutually agreeable regarding the restoration policy for damaged structures, technical cooperation from universities and other railway companies could also be considered.

b.) Establishment of a restoration organization and early launch

It is necessary to establish a system for the disaster response headquarters and other restoration organizations in advance, and to quickly set up the organizations, not only to deal with structural damage caused by earthquakes, but also to utilize all kinds of information, such as rescue and resource allocation. It is effective to hold regular training sessions for assembling and communicating between organizations.

c.) Early decision on restoration policy

Within the current organizational structure of TCDD, no dedicated engineering or technical body responsible for formulating restoration policies has been identified. The respective departments individually manage the damage of natural disasters based on the nature of the event.

Management decisions are needed to determine whether to restore services temporarily or permanently, depending on the importance of the line, and it is necessary to establish a technical organization within the company-wide headquarters to make quick decisions.

d.) Building an organization with a clear chain of command

In TCDD, no initiatives have been identified to review the disaster response process or conduct interdepartmental drills, as is the practice among Japanese railway operators. At present, each department and division responds individually to each disaster as it arises.

To prevent confusion in instructions during a disaster, it is necessary to constantly review the chain of command and introduce the latest communication technology, as well as to set up a disaster response headquarters.

e.) Early restoration through cooperation between organizations

In Türkiye, the AFAD is at the center of the emergency system immediately after a disaster, and administrative organizations and infrastructure organizations including TCDD cooperate to rescue people and ensure safety. However, there is a strong impression that there is a lack of cooperation in the long-term recovery phase that follows. In Japan's recent efforts (Figure 6-55, Figure 6-56), those involved in roads, rivers, and railways have examined a comprehensive restoration process, and have achieved a reduction in the overall construction period and cost.

Collaborating with road and river officials to restore the railway quickly — MLIT

In order to restore the railway facilities damaged by the July 2018 heavy rains as quickly as possible, a contact and coordination committee was established with members from the railway, river and road authorities. The committee coordinated the relevant restoration work, and smoothly restored the damaged railway.

Contact and Coordination Meeting for the Restoration of Railways Affected by the July 2018 Heavy Rain Disaster

Members
- Railway Operators：Department Managers from JR Central, JR West, JR Shikoku, and JR Kyushu
- MLIT：Managers of the relevant section of the Minister's Secretariat, the National Land Conservation Agency, the Road Bureau, and the Railway Bureau

The date of the meetings
- August 10: Coordination meeting with JR regarding restoration of railway services
- August 21: Meeting with JR West and relevant departments of the MLIT regarding early restoration of services
- August 24: Meeting with JR Shikoku and relevant departments of the MLIT regarding early restoration of services
- August 29: Meeting with JR Central and relevant departments of the MLIT regarding early restoration of services
- September 12: Meeting with JR Central, JR West and relevant departments of the MLIT regarding early restoration of services

<Results of cooperation>

○JR Kure Line
- The road management company also removed sand and earth from the railway line. In addition, they provided the national highway land as a temporary storage site for the sand and earth.
- The restoration work on the national highway was adjusted so that the track and electrical work could proceed.
- The restoration period was brought forward (from November to September 9th).

○JR Sanyo Line
- The site of the prefectural road was used as a construction road and work yard for the restoration of the railway line. ・The accumulated soil on the riverbed was used to construct the construction road and work yard.
- The restoration period was brought forward (from November to September 30th).

8

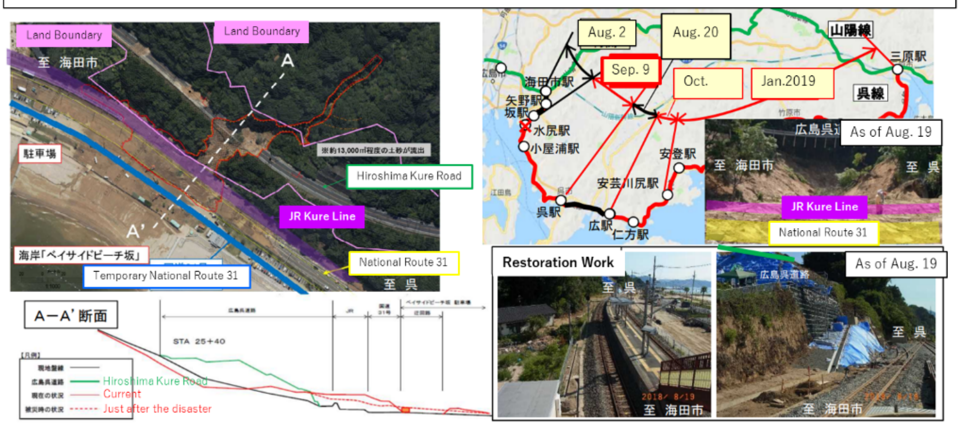
Source: MLIT

Figure 6-55 Example of Restoration Project in Collaboration With Road and River Officials in Japan

Case of Cooperation Aimed at Early Recovery：JR West Kure Line — MLIT

Case Study of Collaboration for Early Restoration (JR Kure Line)

○ In order to carry out the removal of sand and soil from the JR Kure Line, collaboration and coordination with the restoration work on the adjacent National Route 31 and Hiroshima Kure Road enabled the restoration of the JR Kure Line to be brought forward (from November to September 9).
- NEXCO West Japan removed the sand and soil from the JR line. In addition, the Chugoku Regional Development Bureau provided the land for National Route 31 as a temporary storage site for the sand and soil. Furthermore, the Chugoku Regional Development Bureau coordinated the time of day for removal based on traffic conditions.
- After the sand and soil on the tracks was removed, the process of restoring the Hiroshima Kure Road and National Route 31 was adjusted so that work on the tracks, electricity, etc. could proceed quickly.



Source MLIT

Figure 6-56 Restoration Work on the JR Kure Line (Collaboration Between JR West (Railway), NEXCO West Japan, and the Chugoku Regional Development Bureau (Road))

Chapter 7 Conclusion and Considerations for the Future Improvement

7.1 Existing Issues and Difficulties in Türkiye

(1) Issues Relevant to the Disaster Prevention System

Concerning the survey on the disaster prevention system, a sharing session was held during the first mobilization to ensure TCDD's understanding of the usefulness and necessity of the system. TCDD also recognized that capacity strengthening is a challenge, especially with regard to the O&M of such a disaster management system.

At the same time, it was also mentioned in the discussions with the WB and with related parties in Japan that it is essential to strengthen O&M capabilities and systems, such as implementing operating regulations using the disaster prevention system and developing inspection rules for the resumption of operations.

It will be necessary to investigate the internal regulations of TCDD and to consider not only the specifications and functions of the system to be deployed but also the regulations considered necessary for the future enhancement.

In addition, as indicated in section 1.7, some disaster observation networks already exist in Türkiye, which could be utilized for railway operation management. However, the existing observation networks are not designed for railways disaster management.

Therefore, it does not necessarily cover the railway lines, does not observe disasters that pose a risk to railways, and does not have an information-sharing system with railway operators.

DSI and MGM have their own detection and monitoring network for rainfall and river floods. DSI and MGM explained that there are no constraints for information sharing and that they are able to provide the information only if TCDD or the railway operator requests it. Furthermore, UEIM recommended that such data sharing be realized to prevent natural disasters. However, as of 2024, such information sharing has not been achieved.

(2) Issues Relevant to the Development of Laws, Regulations and Standards

The development status of laws and regulations in Türkiye has been identified to a certain extent. There are some advanced disaster management plans and response policies at the national and provincial levels in Türkiye. Their legal effectiveness and status of development are limited. It was confirmed that they are basically post-disaster responses and coping plans. The framework does not clearly state considerations such as infrastructure disaster prevention, including railways.

Furthermore, the local governments and regional AFAD primarily handle post-disaster management within their established systems. Since TCDD is not part of this framework, it must independently carry out restoration activities.

In addition, some railway operators and systems use quantitative decision-making indicators in their standards and regulations for railway operations. Since the above-mentioned framework includes urban railway operators, the disaster response policies and procedures are well organized. However, urban rail operators, especially the newer ones, have no experience at restoration from major disasters. Therefore, they showed interest in whether the above response policies and standards would be sufficient for the early resumption of rail operations as the system becomes more widespread.

It was also confirmed that there is no disaster recovery procedures or plans that have been established in the railway sector. There is no financial assistance scheme for restoration from a disaster as in Japan. In the case of the Türkiye-Syria earthquake, part of the national budget was allocated to TCDD via MOT after the government declared a state of emergency. This enabled TCDD to start restoration work. Therefore, local officials confirmed that restoration will be carried out on a case-by-case basis using local and national budgets. At present, urban rail operators have no experience with major natural disasters and no experience with restoration. Therefore, they do not understand the necessity of consideration for restoration schemes in advance.

(3) Issues Relevant to the Restoration of Civil Structures

Many of the sections of track affected by the 2023 Türkiye-Syria earthquake consisted of ballasted tracks with soil roadbeds. As a result of efforts to restore tracks in various areas, the range of sections where it was possible to run trains expanded in a relatively short time, although the restoration of power supply facilities was still in progress. In the sections where it was impossible to run trains, there was significant damage to structures such as bridges and tunnels, and these were the structures that the survey team investigated at the request of the Turkish side in May 2023. Most of the restoration policies devised by Turkish academic institutions are acceptable to JR East engineers, and the February 2024 survey confirmed that the restoration of structures was being carried out as planned, so it can be said that they possess the necessary technical capabilities for structural restoration design.

As the number of structures such as tunnels, bridges and viaducts increases with the development of high-speed railways, the number of structures that could be damaged in earthquakes will also increase. In this situation, the challenge will be to quickly diagnose the damage to many structures and formulate restoration policies. The following will be necessary to achieve this goal.

○ Strengthening of technical organizations
・ Training of survey personnel for disasters such as earthquakes
・ Training of design engineers
・ Centralized management of structural design data
・Accumulation of internal and external case studies
○ Early establishment of a restoration system
・Development of regulations, etc. regarding restoration systems
・Implementation of disaster response training
○ Cooperation between organizations
・Sharing of observation data, etc.

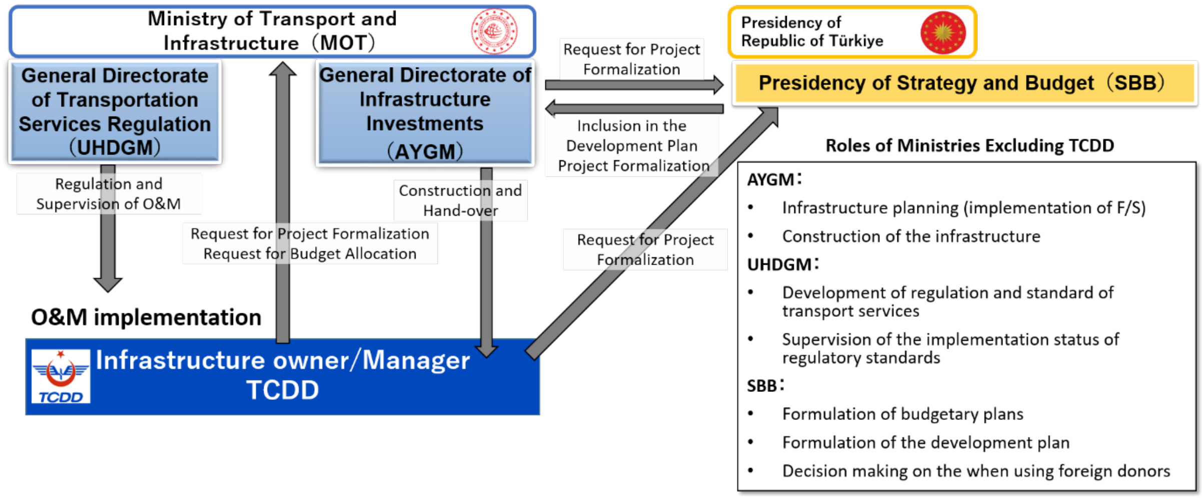
・Building of human relationships to enable organizations to work together to formulate restoration plans

(4) Issues Other Than Above-Mentioned Items

JST identified that rail operators and rail systems receive less attention compared with aviation and ports. It is presumed that the low modal share of rail transportation contributes to these circumstances.
Reflecting this, the UEIM, an independent organization responsible for investigating accidents across the aviation, land transport, and railway sectors, currently employs only three railway investigation specialists among 28 staff members in UEIM, two of whom are seconded by TCDD. According to an interview with UEIM, the two staff members seconded by TCDD are taking the initiative in various regions, but there is not enough personnel available and it is not possible to follow-up on the status of implementing their recommendations and proposals. Although a considerable number of personnel are allocated for aviation and maritime transport, support for the railway sector is limited.
Furthermore, AFAD views the operation and maintenance of infrastructure, including railways, as the responsibility of organizations under MOT. As a result, AFAD explained that MOT should direct and order disaster response activities for each operator.
It should be noted that a certain level of cooperation has been established. For example, there is swift collaboration between AFAD and TCDD in transporting relief supplies and evacuating disaster victims, as well as integrating AFAD operations into restoration plans for urban railways.
It was also noted that urban railway operators are under the disaster management systems of their respective metropolitan municipalities, and the division of roles and responsibilities in disaster scenarios is relatively well-defined. However, current plans lack detailed scenario assumptions and fail to specify the roles of transport operators compared with the comprehensive frameworks of Japan's Arakawa Timeline. It is recommended that urban transport operators develop proactive disaster prevention plans in advance to enhance their preparedness and effectiveness in evacuation and rescue operations during disasters.

7.2 Recommendations for Solving Problems

The JST considered solutions and shared perspectives and information for the issues referred to in section 7.1 and other chapters. Figure 7-1 illustrates the relation between ministries relevant to railway O&M in Türkiye.



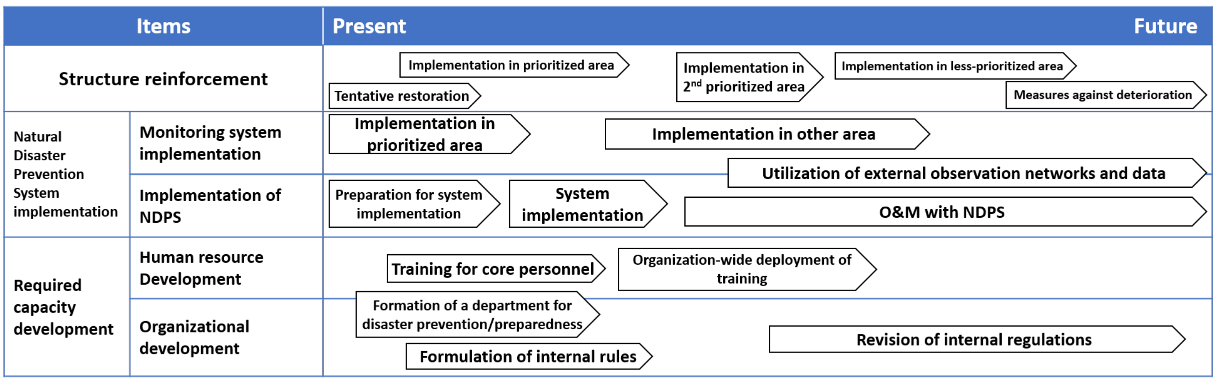
Source: JST

Figure 7-1 Relation Between Railway O&M Entities and Relevant Ministries

Reinforcing structures and implementing non-structural measures are both indispensable to enhancing disaster preparedness in railways. However, as shown in the figure, different entities operate, maintain, regulate, and own railway systems and infrastructures in Türkiye. This organizational structure makes it difficult to discuss comprehensive disaster prevention in railway O&M.

In addition, the railway O&M executors have not been able to convey a strong need for resilience improvement. As a result, there is no national vision for improving comprehensive railway resilience.

In view of this, it is necessary to address high-priority issues while improving medium- and long-term capacity in terms of structure reinforcement and non-structural measures for disaster preparedness. It is necessary to develop organizational structures (people, rules, and mechanisms) to realize these measures. The medium- and long-term work items for resilience improvement based on the issues identified in the survey are shown in the diagram below.



Source: JST

Figure 7-2 Work Items for Future Resilience Improvement in TCDD

As mentioned, basic structure reinforcement is likely to be implemented mainly by Turkish companies. Turkish construction companies already conducted projects abroad and already have a certain level of technical knowledge and experience. Furthermore, TCDD designed and implemented basic restoration works with the cooperation of research institutions such as universities. In addition, Turkish companies are carrying out high-standardization in conjunction with the restoration from the earthquake. It is unlikely that structure reinforcement will be difficult to implement. However, it is assumed that Japanese experiences can be utilized in some specific structures, such as bridges and viaducts. In addition, Japanese companies have been participating in projects to strengthen bridges for road traffic in Istanbul. These companies already participated in a road bridge restoration project in Türkiye and have earned a good reputation. JST confirmed that they intend to utilize local resources and participate in new areas.

There are certain areas where the seismic reinforcement standards for railway infrastructure, as well as the regulatory systems that support the implementation of structural reinforcement, have not yet been fully developed. JST could not confirm whether TCDD is conducting risk assessments similar to those carried out by AYGM.

These may be the result of insufficient inter-ministerial coordination and underdeveloped data sharing and collection systems. In addition, the upgrading of the seismic standard is necessary to consider in conjunction with other infrastructures, including railways, and support may be needed in this area.

In any case, it will be necessary to progress the modernization and disaster restoration of railway infrastructure to achieve resilience, since the TCDD's network includes non-electrified and dilapidated sections. The resilience improvement on TCDD's network requires TCDD to explain the importance of such initiatives to the relevant ministries and secure the necessary budget.

Capacity building in terms of non-structural measures could include the installation of Natural Disaster Prevention Systems (NDPS) for railways. It will be necessary to expand the deployment of monitoring equipment and the development of information system platforms to achieve this. It was confirmed that Japanese companies are interested in participating in areas that Turkish companies cannot cover using their products and O&M expertise.

The medium-term milestone is the establishment and operation of an NDPS. However, to deploy an NDPS, it is essential to establish an adequate organizational structure for TCDD and to build capacity in terms of regulations for the organizational system. Strengthening this organizational structure includes establishing a department in charge of advanced disaster management, creating an O&M system (including internal rules such as SOPs), and establishing decision-making criteria. It is possible to actualize this capacity development by utilizing the O&M expertise of Japanese companies. The use of technical assistance packages from JICA and other donors is also a possibility. In addition to the involvement of the Maintenance Department, the primary counterpart for the Survey, enhancing organizational capacity also requires the participation of administrative and financial departments.

Furthermore, it would be effective to utilize meteorological data, water level data, and seismic observation network data collected by the relevant institutions in Türkiye in the future. As it will be difficult for TCDD to form an observation network solely by itself, it will be necessary for TCDD to pursue the utilization of these assets. However, it is not easy to share information across ministries and agencies, and it is necessary to explain the need and make a consensus across ministries and agencies.

It will be difficult to foster understanding merely by approaching other ministries and government agencies and developing business relationships with the private sector. Rather, it will be necessary to promote this understanding through high-level initiatives, such as technical cooperation with JICA and other foreign donors and by placing emphasis on the importance of utilization of data through an intergovernmental framework such as the Japan-Türkiye Memorandum on Disaster Risk Reduction Cooperation. In other words, to utilize such large amounts of observation data for railway O&M, a platform for utilizing the information is needed, and it can be assumed that the need to deploy disaster management systems will increase.

Moreover, it is estimated that there will be room for Japanese companies to be involved in O&M support after the deployment of disaster management systems. It is necessary to ensure the system's stable operation over a long period of time and to update the system and standards simultaneously. It is estimated that Japanese companies can utilize their expertise in this area.

However, as Turkish railway infrastructure owners and operators have a certain amount of railway O&M knowledge, the scope of assistance will likely be focused on the O&M using the NDPS. It was confirmed that Japanese companies with experience in providing technical assistance to overseas railway operators are interested in participating in O&M technical assistance from the perspective of disaster management.

It should be noted that the SBB, which formulates the national development plans, is aware of disaster prevention issues, and the latest national development plan (12th) includes the word "disaster prevention." In addition, foreign donors have started projects to renovate existing lines, including structural reinforcement. Therefore, there is plenty of room and potential for Japanese companies to participate in the field of railway disaster prevention as a business.

However, the SBB has commented that it is important to seek domestic alternatives in Türkiye, and that technology transfer to Turkish companies should be carried out if Japanese companies participate in the project.

Additionally, AYGM mentioned that the on-site demonstration helped them understand the usefulness of monitoring, but since they are an infrastructure builder, they are not in a position to develop a disaster prevention or monitoring system platform. This means that TCDD needs to manage the installation, procurement, and design of the NDPS, including the monitoring of its existing infrastructure. AYGM can consider implementing the monitoring equipment only on newly constructed infrastructure based on requests from TCDD.

Based on the opinions of the ministries involved in infrastructure development, it will be necessary for TCDD to explain its needs to the relevant ministries and request budget allocations and personnel assignments in the future. Therefore, enhancing TCDD's capabilities must include expanding its ability to explain such needs and develop plans.