"Safety Plan 2008", the new safety guideline of JR East, has come into effect from this fiscal year. Our research approach, which consists of three pillars, has been decided in line with this guideline. This paper will introduce the principal features of the research approach such as evaluation of the safety of transportation and evaluation of the stability of transportation that reflect the value concepts of passengers and thus contribute to management decision making. With respect to the "objectives" of each of these approaches, for approach (1), by causing the sense of values of the passenger to be reflected in the evaluation of safety, risks and the stability of transportation, the objective of the approach is to derive a method of evaluation that conforms with the impressions of the passenger and thus contributes to management decision making. With respect to approach (2), in addition to preventing collisions and other serious accidents that relate to internal causes, the objective is to prevent accidents due to natural disasters and to expand and deepen the areas of research concerning the safety of passengers on the platforms, and the safety of the staff of subcontractors. With respect to approach (3), from past research on enhancing the capability of teams and groups with respect to safety, research that is focused on the study of human attributes and methods of enhancing capability in preventing accidents such as through elucidation of phenomenon of mental voids upon abnormality and risk monitoring has begun.

1 Introduction

In order to further enhance safety that has been steadily strengthened ever since the establishment of the company, Safety Plan 2008, the new five year plan of JR East Group concerning safety, establishes the following four pillars as guidelines for the thoughts and action of every company member:

- Focus on the plan for the development of safety facilities;
- Enhance the level of safety;
- Reform safety management;
- Create a culture of safety;

In order to ensure that these guidelines are achieved without fail, the role played by research and development is important, and for this reason, the approach to research with respect to safety has been established as follows in launching the research and development program for this fiscal year. (Figure 1)

(1) Formation of a method of evaluation towards achieving safe and stable transport;
(2) Prevention of accidents related to railways;
(3) Human factor;

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2 Principal Research Themes and Issues

The following factors constitute the objectives and issues with respect to the research themes that are currently being undertaken based on the approaches explained above towards achieving the Safety Plan 2008.

2.1 Establishment of a Method of Evaluation towards Achieving Safe and Stable Transport
2.1.1 Strategic Method of Evaluating the Reliability of the Railway System as a Whole

The objective of this approach is to develop a method of evaluating the reliability of the entirety of the railway system in a comprehensive manner including safety and stability of transportation. The final target is to develop a method of evaluation of reliability that can support decisions on various measures to be taken.

In research up to fiscal 2002, the frequency and scope of the impact of accidents were quantified using average values based on empirical data and through combining such results, the basic model for the evaluation of reliability was formed as a reliability index. From fiscal 2003, research is being conducted towards the formation of a...
reliability evaluation model that is more practical than the past model by causing the principle of uncertainty including the frequency of accidents and scope of the impact to be reflected in this basic model.

In the current basic model, since evaluation is undertaken using average values, there is the possibility that the estimated value will be lower than the actual value. For example, the same evaluation value will be calculated for a natural disaster of extreme magnitude such as a large earthquake in which 100 people die in one event every 100 years and accidents in which one person dies every year. As a result, it is believed that review utilizing probability distribution with respect to the uncertainty of the frequency of occurrence and scope of impact is necessary.

2.1.2 Creation of a Next Generation Basic System for Train Protection

When it becomes necessary for the crew of a train to undertake emergency suspension of operation as a result of derailment, overturning or damage to the rails, a scheme whereby an emergency stop signal is transmitted using the protective wireless to stop the relevant train is utilized in order to ensure safety. On the other hand, such a system is currently used to protect passengers such as when access onto the tracks by the general public is permitted and the types of use are more diversified than originally intended. As a result, there is a trend for the number of protective wireless signals issued to increase yearly. Moreover, since protective wireless waves issue emergency stop signals to tracks and trains that have no direct relationship to the event that triggers such signals, operations of trains on tracks that are not experiencing any problems also stop and in the Tokyo metropolitan area where train density is high, the impact of protective wireless on train operation is certainly not insignificant.

This research initiative targets the formation of a new train protection system that does not exert impact on trains on tracks that are not experiencing problems in an effort to achieve both safety and mitigation of the impact on train operation upon undertaking train protection.

2.2 Prevention of Accidents related to Railways

2.2.1 Development of a System for the Evaluation of Precipitation Resistance of Slope Protection

In order to assure the safety of train operation during precipitation, it is extremely important to have an understanding of the precipitation resistance of such earthwork structures as banks and slope protection and natural slopes along the tracks and in particular, to understand changes over time and characteristics of stability with respect to destruction caused by precipitation. For this reason, this research initiative undertakes research and development based on actually measured data for natural slopes (Kumanotaira Observatory) and railway banks (Musashino Line) focusing on the behavior of subsoil water penetrating the earth structure during precipitation that causes the instability of such earth structures. Concretely, measured data on the response of subsurface water as a result of actual precipitation are being accumulated targeting the formation of a database of natural phenomena that are highly diverse. Through the development of an analysis system that combines several types of numerical analysis methods, efforts are being made to grasp changes over time of the state whereby such earth structures become unstable to the point of destruction.

These results enable evaluation of the resistance of slope protection to precipitation and provide an indication of the evaluation standards on disaster protection investment such as through slope construction work. Moreover, it is also possible to reflect the same evaluation standard on operational control during precipitation. For example, this may become the base for the next generation of evaluation standards to succeed the new precipitation index (effective precipitation) that is under review for adoption.

2.2.2 Method of Evaluation of Operational Safety through Simulation

While the results of testing using an actual train constitute the principal method of ensuring the operational safety of trains, such testing is extremely labor intensive and severe conditions are difficult to reproduce in such empirical testing thus limiting the conditions that may be set. For this reason, initiatives for forming a method of evaluating operational safety by reproducing train operation using computer simulation are underway in an attempt to reduce testing using actual trains and to cause the results of the simulation to be reflected on the control values for the trains and tracks.

In order to raise the precision of simulation, it is important to verify the difference of the results from those of testing using an actual train but in such empirical testing, data of situations leading to derailment are limited. For this reason, the issue is to achieve safety evaluation of train operation that is as reliable as the results of testing by using actual trains through verification using data of simulated derailment from truck testing equipment.
2.3 Human Factor

2.3.1 Research on Measures to Deal with the Phenomenon of Mental Voids upon Abnormality

When humans encounter accidents or other unforeseen events (abnormalities), the mind becomes blank (called the phenomenon of mental void) thus generating a significantly different psychological state from the norm and in such a situation, the types of human errors that occur also change.

This theme focuses on situations that are not stable or normal that are becoming increasingly important in terms of safety for JR East Group and human characteristics under such conditions will be elucidated and proposals will be made for measures in order to assure the performance of workers under such conditions. Concretely, in addition to undertaking analysis of past phenomena that require attention and of examples of impaired transportation, effective measures that are being taken in other industries in order to assure performance under abnormal conditions will be identified. Based on this, simulation experiments that assume concrete abnormality in railway operation will be undertaken to elucidate changes in human characteristics and performance as well as the types of errors that are prone to occur depending on the circumstances or situations.

From the results obtained through such simulation, concrete measures in terms of people, things, environment, management and other such factors will be reviewed and proposed in order to assure performance of workers under abnormal situations.

2.3.2 Research on Methods of Risk Monitoring Training

Experienced motormen operate trains in a modulated manner controlling the level of vigilance depending on the time and place and pay particular attention to railway signals that require such attention. Moreover, assuming cases of accidents involving humans, such motormen project themselves ahead to matters that need to be arranged in advance.

On the other hand, experienced hostlers give consideration to the characteristics of the train equipment and working environment and pay particular attention to tasks that may lead to breakdown of trains or to dangerous tasks in a sensitive manner and attempt to prevent accidents by controlling the focus of their attention based on the content of the work and the environment.

For this reason, in order to attempt to extract and compile the skills in error prevention that these experienced motormen and hostlers have gained and to share such skills, hearings are being conducted among such experienced staff and in addition to analyzing their know-how, the methods of threat management utilized in the aviation industry are being applied in an attempt to develop methods for enhancing capabilities in preventing accidents such as through monitoring risks. By analyzing the relationship of "capability in risk detection," "capability in attention control" and "skill in allocating pace" that are particularly considered to be constituent elements of risk monitoring, the intention is to propose a training method with respect to risk monitoring capability.

3 Application of the Results of Research

In the research and development of corporations, the early application of the results of such research and development to the business leads to strengthening the management base and is of paramount importance in bringing innovation to the scheme and system of the business. From this perspective, this section will introduce the overview and effectiveness of the principal themes that have already been applied to the business or with respect to which preparations for such application are in progress through the research and development initiative of the past several years.

3.1 Research on Advanced Transportation Stability Indices

(1) Overview

The impact of transportation impairment is currently expressed in terms of such indices as the number of trains cancelled, number of trains delayed and total delay time. However, with these indices, there are such problems as the fact that the scope of the transportation impairment is not readily identifiable and that the impact experienced from when operations are resumed until to operations return to the normal state is not included. In order to resolve these problems, this research effort has established the concept of "people-time evaluation" to be used as an index of transportation stability. This index expresses the impact of the impairment of transportation on passengers in a quantitative manner taking into consideration the following:

① Number of passengers impacted (number of people)
② Additional waiting time in excess of the norm for the passengers who are affected (minutes)
For example, if there are 100 passengers who are delayed by 30 minutes and 200 passengers who are delayed by 20 minutes, the stability index is as follows:

\[30 \text{ (minutes)} \times 100 \text{ (people)} + 20 \text{ (minutes)} \times 200 \text{ (people)} = 7000 \text{ (people-minutes)}.\]

(2) Effectiveness

The table on the right expresses an example of transportation impairment using this index.

By using this index, the scale of transportation impairment may be uniquely expressed using a single index and this also allows comparing the scale of transportation impairment among districts. It is believed that this is the ideal index for comparing the level of seriousness of transportation impairment with consideration given to the impact on the passengers. Moreover, a system has been produced for automatically computing the index by inputting the location of occurrence, time of occurrence and time of recovery from the impairment.

<table>
<thead>
<tr>
<th>Location of occurrence</th>
<th>Time of occurrence</th>
<th>Current indices</th>
<th>New index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan Tokyo</td>
<td>Around 8 o’clock</td>
<td>Deterrnet: 48 minutes, Cancellation: 48 trains (44 minutes to 4 minutes)</td>
<td>23.6 million (people-minutes)</td>
</tr>
<tr>
<td>Suburbs</td>
<td>Around 11 o’clock</td>
<td>Deterrnet: 81 minutes, Cancellation: 71 trains (94 minutes to 3 minutes)</td>
<td>2.04 million (people-minutes)</td>
</tr>
<tr>
<td>End of a district</td>
<td>Around 21 o’clock</td>
<td>Deterrnet: 23 minutes, Cancellation: 6 trains (23 minutes to 5 minutes)</td>
<td>0.35 million (people-minutes)</td>
</tr>
</tbody>
</table>

(3) Future Developments

In order to enhance the depth of the index, research is being conducted on quantifying the passengers’ evaluation and incorporating this into the transportation stability index. Moreover, use of the index in the formation of a train operation adjustment system is also being reviewed.

3.2 Operational Restriction After Earthquakes using the SI Value

(1) Overview

For a railway system that operates in a country such as Japan that is highly vulnerable to seismic events, ensuring the safety of trains in the event of an earthquake is a highly important issue. JR East Group monitors seismic motion using seismographs installed at the wayside of tracks. In the event an earthquake occurs, the safety of the train is assured through commands for operation control such as through slackening the speed or ceasing operation if the seismic motion is in excess of a standard value that is established in advance. While in the past, the gal value was used as index of seismic motion, starting from fiscal 2003 the SI value has been adopted for all existing traditional lines as a new index.

The SI value is an index of seismic motion that expresses the shaking of structures as a result of an earthquake. It is defined as the mean value of the velocity response spectrum in the periodic interval between 0.1 to 2.5 seconds for an attenuation coefficient of 0.2 and the unit used is kine with 1 kine = 1 cm/sec.

\[SI = \frac{1}{T} \int_{0}^{T} Sv (T, h) \, dT\]

Where: \(Sv\): maximum velocity response; \(T\): period; \(h\): attenuation coefficient

(2) Effectiveness

From the review that was undertaken previously, it was estimated that the number of incidences of involving issuing unnecessary operation control could be reduced without any decline in the level of safety. In the case of the example of an earthquake with the epicenter off the southern coast of Sanriku that occurred on May 26, 2003 after adoption of the new system, as seen in Figure 2 operation control was issued in about the same sections as with the gal value that had been used in the past and covered all locations where damage was experienced confirming that the new system provides for the same

![Fig 2: Section where Train Operation was Stopped as a Result of an Earthquake Causing Damage (left figure: SI value; right figure gal value)](image-url)
level of train safety as the index used in the past. On the other hand, with respect to earthquakes that do not cause damage to structures such as the earthquake with the epicenter in the northern part of Ibaragi Prefecture that occurred in August last year, it was confirmed that unnecessary operational restriction commands have been reduced as seen in Figure 3.

3.3 Gale Forecasting Alarm System

(1) Overview
While operation control is undertaken based on the status of gale winds along the tracks, there are elements to this rule that are not necessarily rational such as the fact that operation control is undertaken after the gale is observed and that operation control remains in force uniformly for 30 minutes after the gale has subsided. For this reason a system has been developed for a gale alarm that issues operation control by forecasting the upper limit value of the wind velocity in the near future based on the past to the present wind velocity data.

This system issues operation control commands when either the current wind velocity or the upper limit of the wind velocity reaches the control value and cancels the control when both values fall below the control value.

Instructions on the determined category of operation control (cessation of operation, velocity control and no control) are automatically issued by a program that repeats each step of the procedures shown below for each time element sequentially.

1. Determine the forecast velocity from the observed wind velocity;
2. Estimate the distribution (data spread) of the forecast error by comparing the forecast wind velocity against the measured value of the observed wind velocity;
3. Determine the upper limit of the wind velocity based on the above distribution;

(2) Effectiveness
While there is some spread depending on the examples of individual gale events, about 300 examples of gale events observed at 24 wayside locations and 25 meteorological observatories within the region serviced by JR East Group were investigated and it has been confirmed that the time during which operation control is maintained was reduced by about 30% while ensuring that the safety level of the current rule was maintained.

(3) Future Developments
The development of this system was completed by fiscal 2002 and approved in fiscal 2003 by the Technical Review Committee for the Method of Operation Control During Gale Conditions, a committee of company external specialists. A prototype device has been installed at the Shinano River bridge between Hakusan and Niigata stations on the Echigo Line and installation is scheduled at the Arakawa discharge channel between Shinkiba and Kashiwa Koen stations of the Keiyo Line. In the future, the system will be installed throughout the railway system of JR East Group after awaiting deployment of the required environment for adoption such as the upgrading of the disaster prevention information system.

3.4 Operation Control based on Effective rainfall

(1) Overview
While currently, operation control during precipitation is effected through combining the observed value of the “volume of rainfall over time” and “consecutive rainfall” that are calculated from the data observed by the rain gauges installed at the wayside of tracks, there are elements in this system that are not necessarily rational such as the fact the consecutive rainfall value is reset if a state of no precipitation continues for 12 hours and that unless a state of no precipitation continues for 12 hours, even a small amount of precipitation may cause operation control to be issued.
For this reason, research has been undertaken on the effectiveness of using a simple mathematical model for operation control with consideration given to the impact of past precipitation that expresses an “effective precipitation” index that represents the state in which the volume of rainwater declines through run off or absorption into the soil over time.

(2) Effectiveness
This system has allowed a more accurate representation of the relationship between precipitation and destruction of earth structures and has enabled rational operation control.

(3) Future Development
With the effective precipitation index, an appropriate half-life value that reflects the various precipitation patterns of the area under control was established. In the future, the standard value for control will be established combining three types of half-life values, 1.5 hours, 6 hours, and 24 hours to establish the standard value for operation control in order to reflect the diversity of the causes of precipitation damage along railway tracks and meetings for technical review by specialists are being convened towards early adoption of such a system.

3.5 Track Closure Procedure Support System

(1) Overview
"Track closure" is a method of preventing trains from entering a section of track by displaying the red signal in the vicinity of the location of work being performed in order to assure safety. In the past, telephones have principally been used for procedures in applying for track closure and in order to confirm closure. In order to prevent human error during maintenance work, the "track closure procedure support system" has been developed that uses a mobile terminal for producing work plans that conform to the train operation schedule and for confirming the status of train operation at the site and the commencement and completion of the maintenance work.

(2) Effectiveness
The system is expected to prevent accidents by reducing human error as well as allowing extension of working time by about five minutes by enabling work to commence immediately after a train passes and reduce the procedures for commencement and completion of the work from the current 15 minutes to 3 minutes.

(3) Future Development
Further upgrading will be undertaken based on the results of the trial runs from June 2001 and preparations are underway for applying the system to the Shinonoi Line with respect to appending the functions of the maintenance car course formation system.
3.6 Platform Detection System

(1) Overview
This is a scheme for attaching ultrasonic sensors on the left and right sides of the front and back ends of a train whereby unless the sensors detect a platform, the door will not open even if the door opener is operated. The system is configured from the ultrasonic sensors installed at the two ends of the train configuration, control equipment and alarm system with the connection to the control equipment consisting of a cable for transmitting information. Since the distance and height from the tracks to the platform is constant, ultrasonic sensors that are used for both transmission and reception and these sensors determine whether or not there are structures in the vicinity of the established region by measuring the time from transmission to reception. From this time interval, the distance to the structure is calculated and it is determined whether or not a platform is present. After it has been determined that the entire train configuration is along a platform, the door may be opened when the conductor operates the door opener. On the other hand, when it is necessary to open the doors in the absence of a platform for inspection at the depot or during the maintenance of the train, the system is equipped with an overriding function for forcibly opening the door.

Moreover, in the event the train configuration stops partially misaligned from the platform or the door opener is operated where there is no platform, an alarm light will be displayed and an alarm buzzer will be sounded.

(2) Effectiveness
This system contributes to safety by providing backup in the handling of the doors by the crew in order to prevent the door from opening when a train stops partially misaligned from the platform.

(3) Future Development
This system is scheduled to be adopted in 83 train configurations of the Series 209 trains of the Keihin Tohoku Line in fiscal 2004 and adoption in other districts from fiscal 2005 is under review.

3.7 Image Processing Type Fall Detection System

(1) Overview
JR East Group is making efforts to ensure the safety of passengers on the platforms by installing such systems as emergency stop buttons, platform steps and fall detection mats in stages in the principal stations in Metropolitan Tokyo and in stations where there is a wide berth between the platform of the station and the entrance to the train due to curves. In addition to these measures, an automated system has been developed for detecting a person falling onto the tracks and informing the station staff and motormen that “a person has fallen” using stereo image processing technology for automatically monitoring the entire track. As shown in Figure 8, stereo cameras are installed under the roof of the platform with a single stereo camera covering 40 m and a single platform being monitored using about six stereo camera units.

(2) Effectiveness
Fall detection information is utilized for emergency stopping of trains and displayed on the “guard display” installed on the platform and the “remote control equipment” installed in the station office. The image and position of the fall are displayed on the remote control equipment and the station staff is thus able to confirm the status immediately.

(3) Future Development
The use of this system began on platform 12 of Shinjuku station on July 12, 2004. In the future, extended use with principal emphasis on station platforms in Metropolitan Tokyo will be reviewed.

Fig 7: Position where Train Stops and Conditions for Opening Door

Fig 8: Example of Detection of a Fall
3.8 4M4E Analysis Method

(1) Overview
For JR East Group, “phenomena that require attention” that are “seeds’ of accidents” are generated for the most part through human error and in order to prevent accidents, analyzing such “phenomena” carefully from the perspective of the human factor is indispensable.

“4M4E Analysis” is a method of multifaceted analysis of causes that induce human error and for establishing appropriate measures to deal with such causes. However, there are such problems as “unfamiliarity with the methods of the analysis of the causes that induce errors” and “numerous cases of inadequacy in the substantiation of measures for coping with the causes of errors” and in order to resolve these issues, a method has been developed that incorporates new procedures (① time series analysis; ② 4M why-why analysis; ③ 4E so what analysis) and analysis sheets (① time series analysis sheet; ② structural analysis sheet; ③ detailed analysis sheet by problem groups) in the legacy 4M4E analysis method. (Refer to Figure 9)

(2) Effectiveness
It is believed that errors may be eliminated and measures for preventing accidents formulated in substance through extraction of the fundamental factors that induce errors by correctly identifying the processes through which errors occur and absorbing knowledge and concepts with respect to the human factor.

(3) Status of Application
From fiscal 2004, the application of the 4M4E analysis method to “phenomena that require attention” will be extended to all branches of JR East Group in order to entrench the 4M4E analysis method as JR East Group’s method of analyzing “phenomena that require attention” to ensure prevention of accidents and the recurrence of accidents.

4 Conclusion
This paper has explained overview of to research and development on safety including concrete research topics with respect to the new guidelines shown by Safety Plan 2008. It is believed that applying the results of research to operations at an early stage in order to reform the scheme and system of operations and to strengthen the basis of management is important to the success of Safety Plan 2008. In order to be able to apply the plan to operations in an efficient and smooth manner, JR East Group intends to undertake research with emphasis on the passenger and the field.