In order to steadily achieve the safety tasks indicated in Safety Plan 2008 and New Frontier 2008, the Safety Research Laboratory of the Research and Development Center JR East Group is involved in research and development based on the following three planks: “Preventing railroad related accidents,” “securing safe and stable transport and safety measures for earthquakes,” and “human factors.” In our research and development, the first thing is to utilize the lessons learned from major disasters and accidents in our safety measures, such as the derailing of the Shinkansen during the Niigata-Chuetsu earthquake and the Fukuchiyama Line derailing accident. This is combined with quantifying potential and existing risks to select and concentrate on certain research and development themes. At the same time, we shall go forward with research and development concerning the creation of safety and safety activity indices for our company, so that a preventative safety control structure can be created. This paper describes our thinking concerning research and development, and introduces the aims of our main themes and tasks.

1 Introduction

This is the second year of the Safety Plan 2008. Currently, based on the four planks below, we are developing many different safety measures, including the introduction of research and development results.

- Intensive installation of safety facilities
- Raising level of safety
- Reforming safety management
- Creating safety culture

In addition, our new medium-term business plan, "New Frontier 2008," will start this fiscal year. Of the six planks of this basic concept, the first is, "The constant challenge of providing safe and stable transportation."

In October 2004 a running Shinkansen derailed during the Niigata-Chuetsu earthquake and in April 2005 there was a derailing accident on the Fukuchiyama Line. Both of these were major accidents in the history of railroads. It is an important task for us to learn as many lessons as possible from such disasters and accidents.

2 The Three Planks of Research

Based on these circumstances, we have created our research planks based on the following thinking.

It is said that, "The history of railroad safety is the history of accidents." In other words, the safety of today's railroads is based on the lessons learned from the various accidents of the past. However, if safety measures are totally dependent on experience, then there is a limit to the level of safety that can be achieved. In order to effectively aim at "ultimate safety" in railroads in the future, measures must not only be based on accidents, but it is believed that they must be based on scientific assessments of the overall risks of railroad systems. Furthermore, in recent years there has been a sharp focus on risk management with regard to corporate activities and the concept of objectively assessing corporate risks and taking preemptive measures has become widespread.

As a result, we have decided to promote our research strategy by taking a realistic approach to the risks of entire railroad systems. In general, when technology becomes more advanced, the safety of systems increases, but there is a trend for the scale of accidents to become catastrophic. The goal of accurately assessing the risks in railroads is not only to understand the safety level in our company, but also to quantitatively know what dangers lie in which areas of the system. In other words, we believe that knowing how serious certain types of accidents are and using that knowledge for optimum decision making in safety strategy are very important for our company.

Because of the above, we have decided to approach safety measures by establishing the three planks below based on the risk map indicated in "Reliability Assessment of Entire Railroad Systems" that will be described later (Figure 1).

(1) Preventing railroad related accidents
(2) Securing safe and stable transport and safety measures for coping with earthquakes
  1) Taking on risk management
  2) Coping with natural disasters

Fig. 1. The Three Planks of Research
(3) Human factors

3 The Aims of Research

The aims of these three planks are explained below.

(1) Preventing railroad related accidents

The aims here are to prevent train collisions, derailments and other accidents that are mainly caused by internal factors, secure the safety of passengers on platforms, etc., and expand and deepen the area of research to include the safety of the employees of cooperating companies, etc.

(2) Securing safe and stable transport and safety measures in regard to earthquakes

In order to make the aims of this research easier to understand, we have further divided them into two subdivisions: 1) Coping with natural disaster and 2) taking on risk management. With regard to 1), we aim to expand our area of research into natural disasters that we have not considered to date, such as disasters caused by snow. Concerning 2), we aim to develop methods to comprehensively assess entire railroad systems, including the reliability of safety measures and stable transport.

(3) Human factors

In order to discover the causes of accidents, prevent recurrence and aid prevention, the 4M4E analysis methodology is being introduced. The aim of this plank is research into investigation methods that will appropriately support the human factor point of view and research into new instruction and training methods that give consideration to human factors.

4 Overview of Main Research Themes

In order to steadily achieve Safety Plan 2008 and New Frontier 2008, we would like to describe the main research themes we are currently working on and their aims, tasks involved, etc.

4.1 Preventing railroad related accidents

4.1.1 Research on wheelclimb derailments

Five years have passed since the derailment accident in March 2000 on the Hibiya subway line. Since then, research on wheelclimb derailments has been conducted in many places and the mechanisms that cause derailments have been almost totally clarified. However, there are still some areas in which the conditions and their values are not clear, such as the friction coefficient between wheels and rails which is assumed to have a major effect on derailments. In addition, it is believed that the overlapping of numerous causes leads to wheelclimb derailments, so that it is necessary to clarify the effect each cause has on derailment. Our company has research results and running test data (Figure 2) over the last ten years and we have been clarifying the factors that are effective in preventing wheelclimb derailments.

Furthermore, with regard to the friction coefficient between wheels and rails, we have been doing research by conducting derailment simulation tests using truck-testing devices. These tests have been conducted to prevent low-speed wheelclimb derailments and have involved the use of friction adjustment agents to maintain friction within certain ranges. In the future, we plan to conduct in-depth research on the use of friction adjustment agents, and appropriate specifications for trucks, such as the specifications for axle box suspension rigidity.

![Fig. 2. Research on W wheelclimb Derailment by JR East](image-url)
However, because the scale does not consider the time that the wind has an effect, there is some doubt as to whether it is appropriate for assessing safety for phenomena such as train drafts which fluctuate greatly within a short period. Therefore, we estimated the allowable range of train drafts at stations without bypass tracks from the viewpoint of passenger safety by conducting attitude stability assessments of test subjects.

4.1.3 Research on Short-Circuit Running of Maintenance Cars

The maintenance cars used to maintain tracks have grown in size and the largest one have a gross weight of over 60 tons. Conversely, electric trains and diesel cars have become more lightweight and weigh about 30 tons. At present, measures to prevent trains from entering sections occupied by maintenance cars are dependent on the awareness of workers. Therefore, we developed a backup system that prevents collisions between trains and maintenance cars by having maintenance cars use short-circuit running similar to those used by regular trains so that signals will display stop signs (Figure 4).

This system was realized by developing a clamp shunt that can be used with maintenance cars and that short circuits the track circuit but does not affect crossings. The practicality of this system was verified by running tests and trials on the Chuo Line (between Uenohara and Kobuchisawa), and we are currently introducing this system to other districts where the conditions allow introduction. We plan to continue research to allow this system to be used with CTC districts and districts that have different track circuit systems.

4.2 Securing safe and stable transport and safety measures in the event of earthquakes

4.2.1 Taking on risk management

We are approaching risk management from the viewpoints of objectively assessing the risks in railroad systems and taking preventive measures. Therefore, our approach involves the three following points of view: “Creation of a value axis,” “research into human factors” and “construction of a quantitative safety assessment method.” Here, we shall introduce our research into the “creation of a value axis.”

4.2.1.1 Reliability assessment of entire railroad systems

We are developing a methodology that will comprehensively evaluate the reliability of entire railroad systems, including safety, stable transport and social effects. Figure 5 shows an example of an “Accident Risk Map for Railroad Systems.” Items on the upper right of the map have the highest frequency and have the greatest effect when they occur. Items in the upper right can be moved to the lower
left by implementing various safety measures. As an example of this, the risk of train collisions has moved to the lower left with the development of ATS systems, and the remaining risks involve those items concerning man and machine interface.

This map requires a third axis. That is a value axis that adds the social values. For example, the social assessment of an accident or transport problem will differ greatly depending on whether the cause was an internal or external factor. The creation of a “risk map” will lead to greater safety in our railroad systems and indicate the tasks that we must solve. Although it is necessary to discover all possible risks and improve mapping accuracy, this study has helped in the creation of the aforementioned “three planks of research.” In the future, we shall solve the task of creating a value axis, and we hope that it can be used as an index for the safety measures and safety activities of our entire company.

4.2.2 Coping with natural disasters

With regard to natural disasters, we have completed development of the “Gale Warning System,” “Earthquake Operation Restrictions based on SI Values” and “Operation Restrictions based on Effective Rainfall.” All of these systems have been officially adopted or are in preparation for official adoption. In the future we shall conduct research on measures for heavy snowfall that still have many remaining issues to be addressed and earthquake measures based on the lessons of the Chuetsu earthquake.

4.2.2.1 Gale Warning System

The present train operation restriction rule applying to strong winds is based solely on maximum wind velocity measured by gauges and are applied equally regardless of whether it is a momentary gust or the sustained wind speed. Therefore, this rule is one of the reasons to cause disruptions in train schedules. In order to solve this problem, we have developed an operation restriction system (Gale Warning System) that uses predictions of wind speeds (Figure 6). The Gale Warning System can be expected to reduce the time when operation restrictions apply while maintaining the same level of safety as the present rules or better.

4.2.2.2 Earthquake Impact Assessment System

As part of the Shinkansen High Speed Project that is aiming at a maximum speed of 360 km/h, various sorts of R&D and tests are being conducted. With regard to earthquakes, there is a need to take measures to reduce the increased risks from higher speeds to within the allowable range; however, no method of quantitatively assessing the earthquake risks for railroads has been established. Therefore, with the aim of developing a methodology that can quantitatively assess the risks during earthquakes for the entire Shinkansen system, we have been developing an earthquake impact assessment methodology that combines the following evaluation parameters: An earthquake activity degree model, running stability of cars during earthquakes, the earthquake resistance of viaducts, the warning properties of earthquake early detection systems, etc. Furthermore, we have developed application software in order to effectively implement the risk assessment work on PCs and to represent the results in a visual format (Figure 7). The various attribute parameters will allow a quantitative understanding of the effects of earthquake risks, and we hope that this can be utilized for earthquake risk management for the Shinkansen.
4.3 Human Factors
In order to construct a preventative safety management structure that takes every aspect of the human factor into consideration in every way that people are involved, and to optimize the boundary for humans in order to prevent accidents from occurring, we are involved in the following approaches: 1) Prevention of human errors; 2) instruction and training methods that consider the human factor; 3) securing performance in emergency situations; and 4) preventative safety management. In this paper, we shall introduce the research themes for 2) and 3).

4.3.1 Development of 4M4E training and support tools
From fiscal 2005 we have been using our version of “4M4E analysis” that we developed in fiscal 2004 to analyze “items that require caution” that are caused by human error. In order to conduct accurate analysis there is a need to have knowledge about human factors and thoroughly understand the basic concepts. Therefore, we developed the “4M4E Analysis Training/Support Tool.” The “4M4E Analysis Training Tool” is made up of five scenarios, including “Knowing the danger of becoming accustomed to something” and “Understanding errors during emergencies.” This tool uses a problem/explanation format to teach knowledge about human factors and the points in analysis (Figure 8). On the other hand the “4M4E Analysis Support Tool” will provide advice and support about human factors when analyzing “items that require caution.” Whereas the training tool is the basic part, this is the practical part which will help to improve error analysis skills, and even personnel with little experience will be able to provide analysis of a certain quality.

4.3.2 Research on risk monitoring training methods
The risk of operating errors will depend on the work, and even for the same work it will change according to the circumstances. In this research, we collected errors and conditions that required caution through interviews with veteran engineers, and organized the measures that can be used to prevent errors (Figure 9). As a result, we were able to divide the errors that require special caution into “five types” and the situations that can lead to errors into “three dimensions.” Furthermore, with respect to “measures to prevent errors” we found that they are being taken according to the contents
of the errors. We deduced that veteran engineers had two cycles that they used to continuously improve their error prevention skills. The first is a “risk monitoring cycle” based on their accumulated knowledge about situations that require caution in which they predicted and detected risks according to the work conditions so as to avoid risks. The second is a “risk sense accumulation and development cycle” in which they reflect on their own past dangerous situations and prevent future errors based on the causes of those dangerous situations. In the future, we shall assess error prevention skills through discussions in a model work place and develop specific education and training methods.

**5 Conclusion**

Communication with branch offices and front line employees is indispensable in order to utilize the results of research and continuously improve the safety and stability of railroads. In order to steadily fulfill the guidelines presented in Safety Plan 2008, we shall continue to conduct research and development centered on passengers and front line employees in the future by accurately comprehending the role of research and development and by making efforts to utilize research results in actual work as soon as possible.