A train collision accident occurred on December 5, 1988 at Higashi-Nakano Station on the Chuo Line, resulting in the death of a passenger and the driver. With a resolve that such an accident should never occur again, we declared the following year, 1989, to be the starting point for increased safety. We took various measures such as moving up introduction of ATS-P automatic train stop devices and opening training centers at individual branches, and we established the Safety Research Laboratory on April 1 as specialized organization to comprehensively and scientifically study safety.

Since our start 25 years ago, we have needed to deal with how to prevent accidents from occurring in the first place instead of just dealing with the aftermath of accidents that occur. This remains the mission of the Safety Research Laboratory today, and promoting R&D on all aspects of preventing railway accidents has been an unchanging theme of our activities for 25 years.

In the 1990s, more safety issues came to light as result of a train collision accident at Kinomiya Station, an accident at Mito Station where maintenance personnel were struck by a train, a derailment accident in the yard of Kagohara Station. We also participated in the investigation of major accidents such as the 2004 Joetsu Shinkansen derailment in the Niigata-Chuetsu Earthquake and 2005 Uetsu Line derailment accident, going forward in R&D on countermeasures with a focus on the causes of the accidents. As a result, we have advocated prevention before the fact while at the same time making efforts in preventing reoccurrence of accidents, and I believe we have played a role in increasing railway safety though those efforts.

The following covers some of the major successes in R&D in individual fields over the past 25 years.
of 4M4E analysis by using the training tool concurrently with an analysis support tool named “Horisage Kun” (Mr. In-depth Study).

• Support tool to learn lessons from incidents experienced by others
In considering countermeasures against accidents, it is important to learn from incidents such as past accidents and accidents that occurred at other workplaces. But it is no easy task to learn lessons from accidents one did not experience first hand. We thus developed a tool where discussions on experiences such as accidents that occur at other workplaces are prompted through analysis flowcharts and worksheets so one can put himself/herself in the place of others. This has been used at individual workplaces since 2013.

• Education and training from a human factor perspective
To promote workplace education that introduces the perspective of human factors, we have been working to computerize crew education and training, track maintenance personnel training to prevent being struck by trains, and other training in line with the advance of computer technologies. In those efforts, we developed attractive software and easy-to-use systems. Maintenance vehicle driver skill improvement training tools (Fig. 1), for which development started in fiscal 2008, teach about human errors that often occur when using maintenance vehicles and enable skills to be learned for preventing accidents due to errors. These training tools have a structure that allows users to experience situations in a manner close to the real thing through video and computer graphics based on actual case examples, and they allow active learning. They have been used from fiscal 2010 for training at JR East and at partner companies. The tools also earned the Minister of Economy, Trade and Industry prize at the seventh Japan e-Learning Awards as a human error prevention program for leaning practical skills.

• Clarification of human-machine system
In fiscal 1996, we analyzed incidents of passing stop signals recklessly that occurred since the ATS (automatic train stop) system was installed in 1966 to identify characteristics of those incidents and the frequency at which they occur. Based in the results, we studied measures such as those for improving safety in sections with the newer ATS-SN system.

Moreover, we also studied installation of an accident-prevention-type driver’s cab simulator and appropriate work and equipment layout. This was done to approach the issue of preventing passing of stop signals recklessly from a human-machine system perspective. We have been able to apply the achievements of studies to design of actual trains by means such as modification of the driver’s cab ATS-P interface.

• Making use of lessons learned from the 2011 Tohoku earthquake and tsunami
After the October 2004 Chuetsu Earthquake, we revised our manual on actions to take in large earthquakes to include content on the importance of the initial response system and confirmation of safety of passengers and crews. We also created a portable version of the manual. Furthermore, we put together an earthquake risk management manual that allows us to plan and implement effective training so personnel would be able to take appropriate action in case of an earthquake.

In the March 2011 Tohoku earthquake and tsunami, we learned the lesson that flexible response according to the situation led to fewer casualties. We thus developed a method of image training for irregular situations to enable danger to be anticipated and flexibly dealt with according to the situation so as to protect the lives of passengers and employees in the event of accidents and other troubles or disasters. We also proposed specific conditions and directionality for measures for evacuation guidance for use in the event of an earthquake or tsunami.

• Accident prevention from a perspective of human factors
We issued documents on key points for preventing accidents and on human factors regarding safety as means of supporting prevention of human errors at the front lines. Through those, we worked to raise employee awareness of human factors.

Moreover, we tested a safety portal site (hereinafter, “safety portal”) at the Omiya Branch in October 2005 that serves as a venue for absorbing knowledge and skills related to human factors to enable efforts to be made autonomously for preventing occurrence and reoccurrence of accidents. The safety portal was opened across JR East on the company intranet in April 2007.

The concepts behind the safety portal are “regularly providing information helpful in raising safety abilities on the front lines” and “ability to easily search for information when the front lines need it”. The head office Safety Planning Department and the Safety Research Laboratory are using that to regularly provide information. The Safety Research Laboratory in particular has been providing human factor news content with a theme of human factors. Currently, a communication function is being developed to allow exchange of information on the safety portal.

Fig. 1 Maintenance Vehicle Driver Skill Improvement Training Tool
2.2 Safety Assessment

R&D has been carried out on indexes such as those to decide priority in taking safety measures and on transport stability indexes taking into account the impact on passengers. This was done from a perspective of assessing safety of the railway system as a whole and preparing for new risks.

- Efforts in risk assessment for railways as a whole
  As a result of solid safety measures taken since the inception of JR East in 1987, railway operation accidents have decreased year after year to less than half the number in around 2000 as occurred when the company started. On the other hand, effects of those measures are decreasing, and the need is increasing for safety measures taken from a scientific approach instead of just relying on experience and intuition.

  We are thus working to develop a method that will allow application of the concept of risk analysis in railways and proposal of necessary measures. Risk is generally engineering risk calculated objectively by combining probability and consequence. But as social risk weighting items such as operators’ responsibility in terms of risks needs to be considered, so we are studying an assessment method where risks with internal causes and risks with external causes can be compared (Fig. 2).

- POINT index of transport stability
  Data seen in terms of railway operation, such as number of trains canceled and delayed, had traditionally been used to express the scale of transport disorders. However, there were no ways of expressing that from the customer’s perspective, making it difficult to consider prioritized countermeasures.

  We thus came up with what we call the Personage Of Influence on Transportation (POINT) concept. In that concept, as the impact on customers, length of time customers were inconvenienced, the number of those customers, and cause of transport disruption are assessed together and the results of that assessment subsequently ranked on a 1 to 9 scale.

  POINT was introduced at the Tokyo Control Operation Center in fiscal 2005 and subsequently gradually expanded to major lines. It is used as an internal index to measure impact on customers when transport disruptions occur.

2.3 Safety Systems and Maintenance Work

R&D is ongoing for building a new signal communications system and improving safety of maintenance work.

- Building a new signal communications system
  Right after the inception of the Safety Research Laboratory, we set up a committee to study a next-generation signal communications system in order to clarify basic design of signal communications systems. The committee identified deviation from reliance on track circuits, control with mainly onboard devices, and use of digital technologies as the directions we need to aim for.

  For control with mainly onboard devices, we worked in fiscal 1991 to develop a pattern-type automatic train control (ATC) system to replace ATC on the Yamanote and Keihin-Tohoku lines. And in 1996, that work was taken over by a project team set up at the head office and such control was put into practical use as D-ATC.

  To fully achieve that proposal, we started development in fiscal 1995 of the new Advanced Train Administration and Communications System (ATACS) based on digital wireless communications. The project team also took over work on ATACS, with that system being put into practical use on the Senseki Line in 2011.

- Train control system for regional transportation lines
  The semi-automatic block system electronic blocking system (hereinafter, “electronic blocking system”) introduced to regional lines from fiscal 1986 is coming up on time for update as it has been in use for more than 20 years. Moreover, much signaling equipment has been set up at the wayside, and maintenance costs for those are increasing. To replace the electronic blocking system, we are developing a low-cost control system for regional lines that uses general-purpose wireless technologies as new equipment where various wayside equipment is consolidated in a compact manner. The target for introduction of that system is the Koumi Line, which is a line with electronic blocking.

- Prevention of level crossing accidents
  In prevention of level crossing accidents, we are making efforts in areas such as development of novel level crossing designs and highly visible barriers with a goal of developing measures to follow current obstruction detecting devices. In those efforts, we adopted a new next-generation overhead-type level crossing at a model crossing for the Yamagata Shinkansen where accidents have proved to be a weakness of the line. We also developed a red and white large-diameter barrier bar with increased barrier strength and internationally used red and white coloring to increase visibility so as to prevent intrusion to the level crossing after the barrier is lowered. Those barriers have been introduced to multiple level crossings.
• Increasing safety in maintenance work
Work started on building a safety system for track closing work in light of a derailment accident between Otsuko and Isohara on the Joban Line in October 1989. We also worked on developing a train approach warning system using GPS and wireless technologies starting in fiscal 1993 as a result of workers being fatally struck by trains at Mito Station on the Joban Line and at Kashimadai Station on the Tohoku Line. However, that warning system did not come into practical use due to factors such as costs of the technologies at the time.

With cost reductions and increased accuracy of GPS due to it being in wide use now, we are working to develop a train warning system for sections without track circuits and train approach warning device that can be applied to multi-line sections.

From fiscal 1998, we worked on developing a system utilizing general-purpose technologies to support procedures for track closing so as to prevent mistakes in procedures at track closing work. A maintenance vehicle route creation function was added, and the system was introduced to the Shinonoi Line in fiscal 2006. Currently, development is underway on a function to handle doubling of track to allow the system to be deployed across the JR East area.

• New type of Shinkansen confirmation car
Development of a shunting vehicle automatic driving system started in 1991, but automatic driving proved difficult to implement on conventional lines, and the system did not reach practical use. However, the accomplishments of that development combined with those of a route monitoring system were put to use in a new type of confirmation car (Fig. 3). That car uses image processing technology to automatically confirm safety of the track before the first train run of the day, and it has been put into practical use. The new confirmation car was introduced to the Nagano Shinkansen when that line opened, and its accomplishments have led to it being introduced on all Shinkansen lines.

2.4 Rolling Stock and Passenger Safety
Efforts have been made in research on stamping out flange climb derailment both for rolling stock and for track. We have also conducted research on new methods of assessing overturn and R&D in areas such as platform detectors from a perspective of increasing safety at the point of contact between trains and passengers at stations.

• Clarification of derailment phenomena
With a goal of theoretically identifying derailment phenomena, we have worked on analysis by simulation of vehicle dynamics and measurement of running data (wheel load between wheels and rails, lateral force, angle of attack, etc.) on actual trains to verify simulation results (Fig. 4).

Efforts are also in progress for discovering the causes of actual derailment accidents such as derailment of bolsterless bogies at service line turnouts and for proposing countermeasures and management standards found from re-creation tests with active such as collision of maintenance vehicles and put that into practical operation between fiscal 2001 and 2003. We also developed a point splitting prevention device and introduced that to all Shinkansen maintenance vehicles in fiscal 2007.

To further increase safety for maintenance personnel, we also developed a new transceiver for track maintenance. That transceiver can identify the location of and distance between wayside workers and maintenance vehicles when a maintenance vehicle will pass the track adjacent to a section where maintenance work is being performed and warn both that the vehicle is approaching a maintenance section. This was introduced to JR East Shinkansen lines starting in fiscal 2010.

• Maintenance vehicle short-circuit run, etc.
To prevent collisions of trains and maintenance vehicles that are becoming increasingly larger, onboard short-circuit devices were developed where track circuits are short-circuited and electronic train detectors are not shunted. Those were developed for maintenance vehicle short-circuit run, and we have started introducing them on sections where such operation is possible.

Work is also ongoing for development of a maintenance vehicle location system that sounds a warning to prevent road railers from mounting the wrong track and maintenance vehicles from entering closed track sections.

Fig. 3 Shinkansen Confirmation Car

Fig. 4 Running Test
duty cars. We continue to accumulate knowledge on derailment accidents at low-speed running and on research items such as the relation between friction coefficient at the rail-wheel contact point and derailment accidents. And we have also proposed measures to improve on factors that influence derailment.

Research will continue to be made on technologies intrinsic of railways. In that, we will work to improve technologies related to derailment and to pass on technologies, clarify the mechanism by which the friction coefficient between wheels and flanges increases, and demonstrate specifications and management methods for track and wheels where flange climb derailment will not occur.

- Research on resistance to overturn from wind
Shinkansen trains running on standard gauge track have high overturn resistance, and noise barriers installed on many sections have high wind shielding effects. Verification of the wind shielding effects of noise barriers was done by measurements in wind tunnels and on actual trains, and we confirmed that criteria for wind speed at which service is suspended could be eased under some conditions from 30 m/s to 35 m/s even while maintaining safety. Based on those findings, criteria for operation control under strong wind were changed in December 1995, and transport disruptions due to wind were greatly alleviated.

We are also proceeding with efforts in confirming suitability of operation control using the “Detailed Equation” proposed by the Railway Technical Research Institute in 2003 to allow detailed evaluation of resistance to overturn by rolling stock under wind.

- Development of impact absorbing structure for drivers’ cabs
After a level crossing accident at the Osuge level crossing on the Narita Line in September 1992, we conducted research for analyzing impact in order to secure a survival zone in the train in impacts with trucks and the like. In order to secure safety for passengers and drivers, we studied a body structure that can absorb impact by setting an appropriate crushable zone at the front of cars (Fig. 5). The results of studies were applied to design of series E231 and later cars.

- Ultrasonic platform detector
Passengers might fall off onto the track if part of a train stops at a location away from the platform due to error in the driver applying the brakes and the conductor opens the doors there. In order to prevent such incidents, we have developed an ultrasonic platform detector as a safety device that detects the platform and prevents doors from being opened in locations without a platform. We started using that in 2006 on the Keihin-Tohoku Line, and are gradually expanding the lines it is used on.

- Safety Research Laboratory type system for automatic transmission of train protection radio signals
The Safety Research Laboratory type system for automatic transmission of train protection radio signals detects collisions, derailments, or train overturns to send notifications if those incidents occur. Notifications are sent by a method where such information is automatically transmitted using train protection radio. In its development, we utilized a judgment algorithm of a derailment detector developed by the Technical Center and created a new detection system with a function added to detect train collision and overturn using existing acceleration sensors. The system has been introduced to the lead cars of series E233 and later trains on the Keihin-Tohoku Line.

2.5 Natural Disaster Prevention
The Disaster Prevention Research Laboratory was started in February 2006 as a response to the December 2005 Uetsu Line train derailment accident. Before that, research on natural disaster prevention was conducted within the Safety Research Laboratory. The following is a short introduction to achievements in that area by the Safety Research Laboratory where we worked mainly by a human-centered approach of building appropriate methods for train operation control.

- Appropriate methods for train operation control
In the area of rainfall-related disasters, which make up a large portion of natural disasters, we researched a method of train operation control using effective precipitation to improve safety and reduce downtime. The method developed was introduced in fiscal 2007.

After the derailment and fall of a train from the Amarube bridge at the end of the Japanese National Railway era, we worked on a strong wind prediction method applying statistical methods to overcome the issue of strong winds. As a result, a strong wind warning system utilizing that method was introduced to the Keio Line in 2005 and has been deployed to all lines since 2010.

In the area of earthquakes, we studied introduction of SI units with greater correlation to structural damage than gal units. Those units were introduced to train operation control for conventional lines in 2003 and Shinkansen lines in 2005, enabling precise operation control.

3 Conclusion
This concludes our simple introduction to the achievements of the Safety Research Laboratory over the past 25 years. We intend to continue to strive in R&D in the next 25 years and beyond to provide safe railways, with a goal of achieving the ultimate levels of safety in railway transportation.