Decision Support System using monitoring devices on in-service vehicles

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East Japan Railway Company

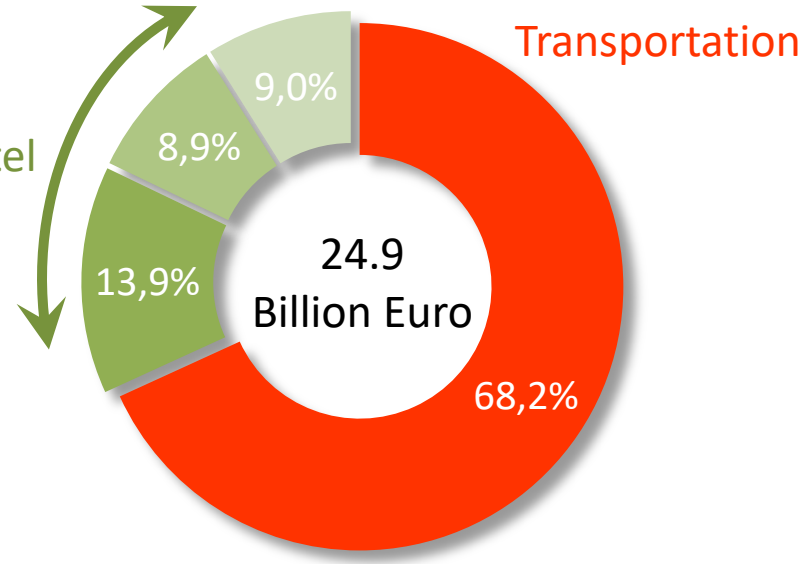
East Japan Railway Company (JR East)

Business Portfolio

JR East Group Information

- Operating Revenue
  24.9 Billion Euro
- Operating Income
  4.2 Billion Euro
- Railway Network
  7,457 km
- Number of Passengers
  17.4 Million/day
  6.4 Billion/year

Business Portfolio



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- Decision about the investment

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- Track Materials Monitoring System
- Installation Plan

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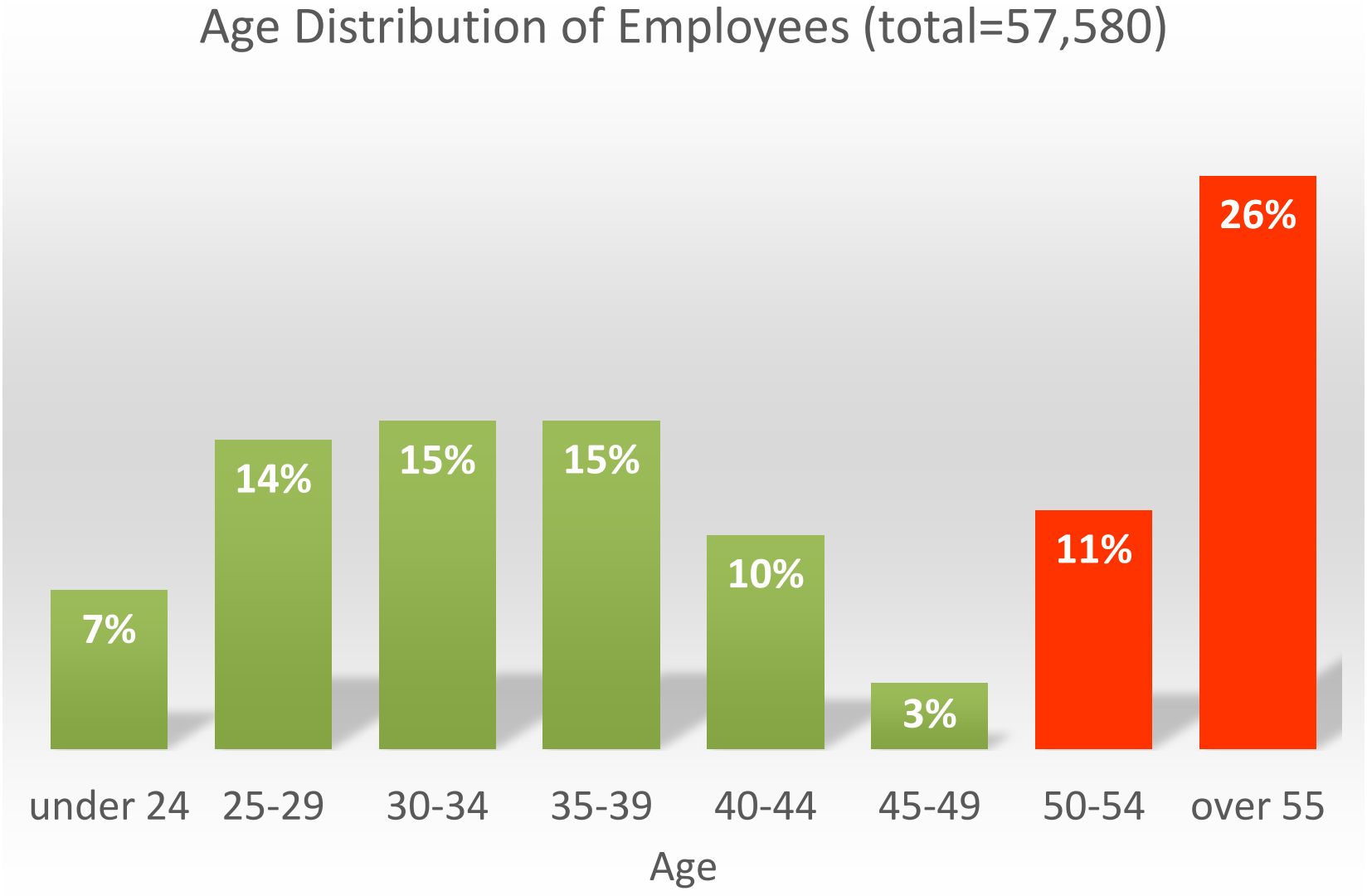
- Rail Weld Irregularities

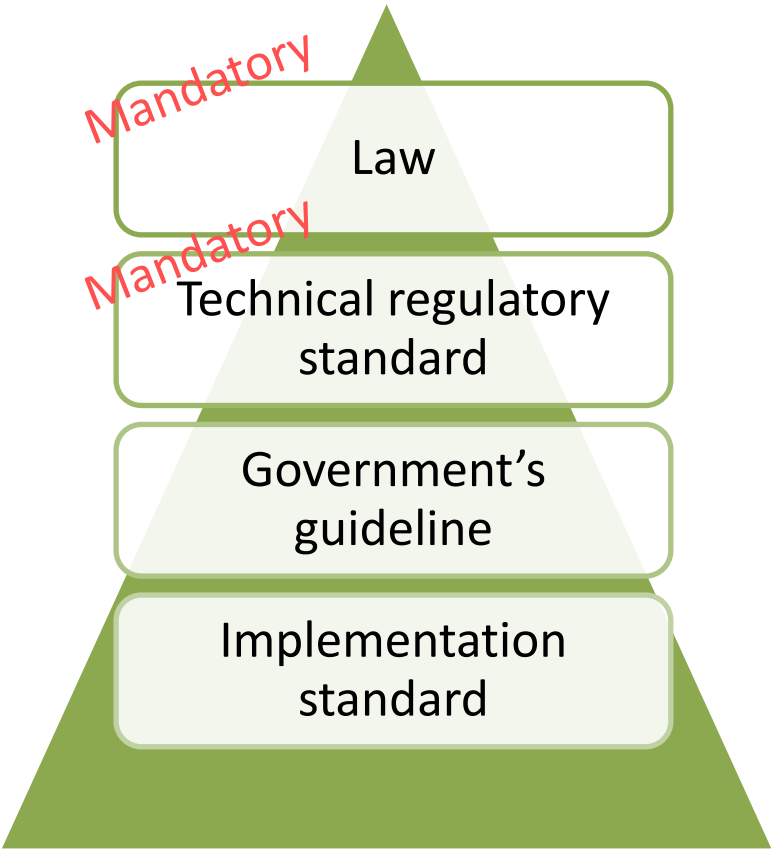
5 Summary

Motivation and Objective

Motivation and Objectives



Motivation and Objectives



The structure of law and regulations

Technical regulatory standard

Patrol inspection shall be conducted for the main track and overhead contact line installed over the main track, according to the situation of the section block and traffic conditions of trains.

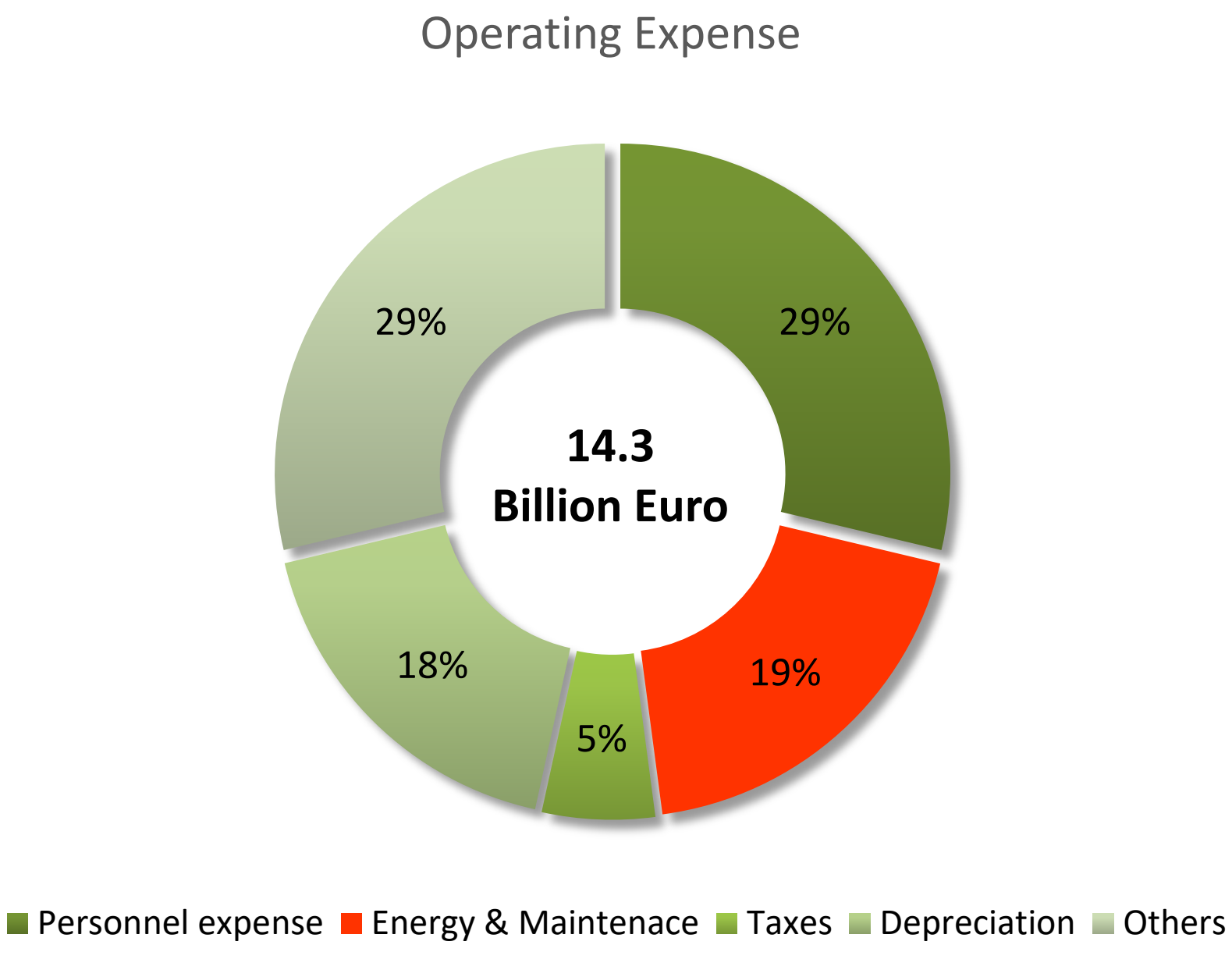
Government's guideline

Details of frequency, timing, method, etc. of the patrol inspections shall be determined considering the surrounding circumstances.

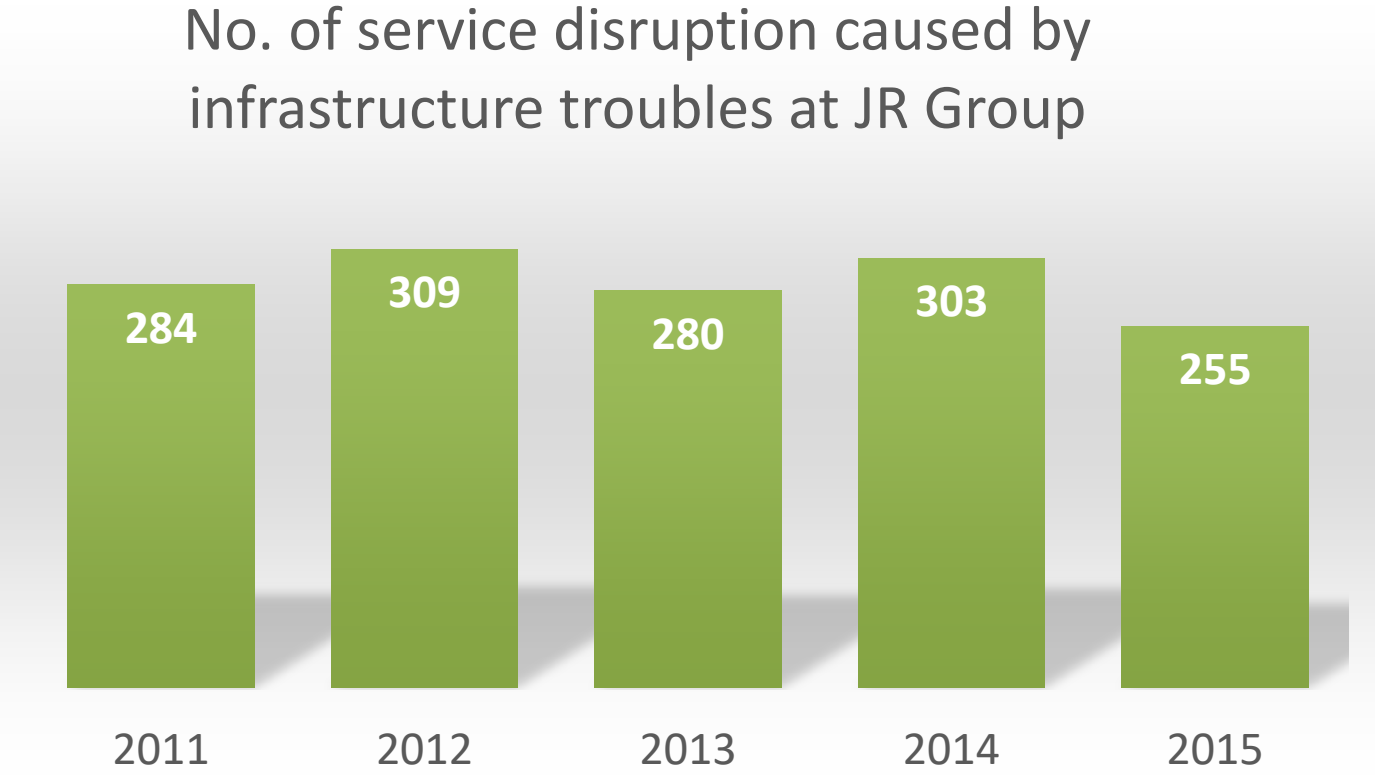
Implementation standard

Grade	1st	2nd	3rd	4th
MGT	25-	15-25	5-15	-5
By train	Every 5 days	Every week	Every 2 weeks	Every 3 weeks
On foot	Every week	Every 3 weeks	Every 6 weeks	Every 12 weeks

Motivation and Objectives



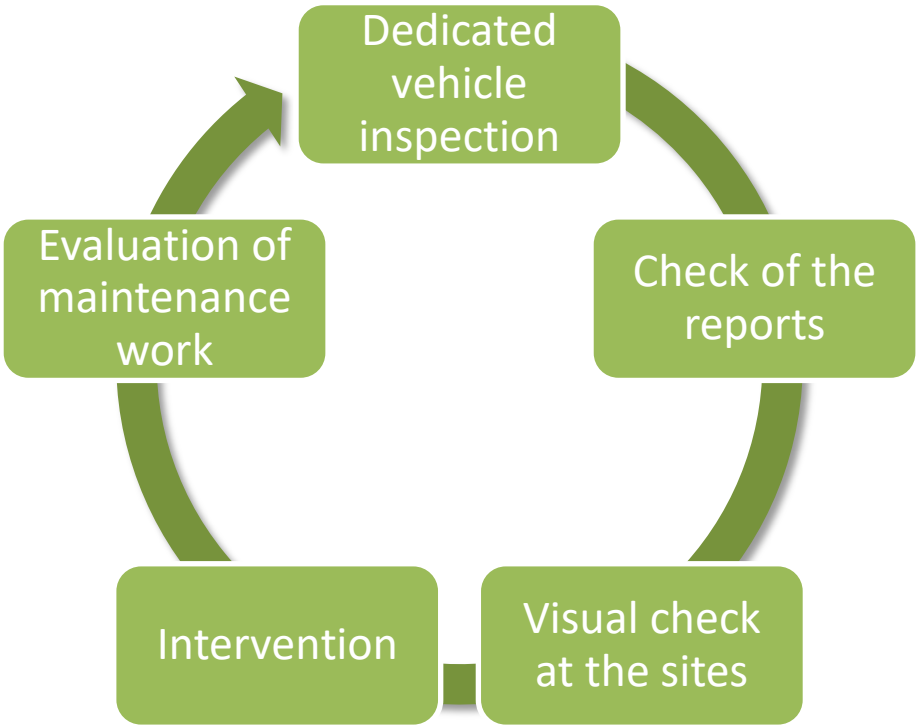
Motivation and Objectives



- JR East has formulated 5th group management vision to aim to renew the courses of action for the group going forward since 2012.
- JR East aim to reduce the number of service disruptions caused by railcar and equipment malfunctions attributable to JR East.
- Primarily, JR East pursues the reduction of the number within an around Tokyo area to one-third the level of 2012.

Dedicated Measurement Vehicles at JR East

- JR East has the dedicated measurement vehicles called East-i for track inspection.
- Two types of the vehicles, electric and diesel, are operated to cover all lines.
- The vehicles are operated to measure tracks every 3 months.
- The 8 parameters of measurement are acquired each inspection.
- Urgent data relating to severe threshold exceedance will be transferred to control center by attended inspector.
- Measurement reports relating to threshold exceedance are informed.



Decision about the investment

- Many researchers and engineers have indicated that CBM approach will allow railway sectors to reduce maintenance and renewal expense to range from modest 10% up to 50%.

- However, some engineers at JR East have doubts about the estimation regarding cost reduction, because JR East has already inspected the tracks 4 times a year to be enough data to prevent repetitive intervention due to inappropriate actions, even though monitoring system is installed each line.

- Also, monitoring tracks frequently, one of the important CBM activities, takes such high cost that recovers the investment.

- We decided to install about 40 track geometry measurement systems and track materials monitoring systems on in-service vehicles in order to relieve workload relating to track patrols and visual inspection walking along tracks while having an expectation of cost reduction and continuing research.

Overview of Track Monitoring Devices

Track Geometry Measurement System

Inertial Unit

190kg

Differential Unit

190kg

Control Unit

- The inertial unit comprises of an accelerometer, a fiber-optic gyroscope, two-axis rail displacement sensor all mounted in the same enclosure.
- The differential unit has components which are an accelerometer and two-axis rail displacement sensor to compliment accuracy in low speed running.
- The control unit consists of power supply module, data transfer module, and UPS.
- Inertial mid-chord offset method (IMOM) designed by Railway Technology Research Institute (RTRI) in Japan is used for geometry outputs.
- These units were developed considering service car body mounted to survey heavily used lines without interrupting the regular traffic.

Track Geometry Measurement System

- The versine method has been used for track inspection since railway operation started in Japan.
- JR East specifies values for remedial actions concerning the longitudinal level and alignment using 10 meter chord versine method as management of rail irregularities.
- This is the reason why inertial mid-chord offset method (IMOM) had developed.
- The IMOM is similar to conventional inertial measurement method regarding measurement principles. However, JR East do not have to change the management rule for track irregularities because the output's waveform is compatible with 10 meter chord versine.
- Also, 10 meter chord versine method includes information about a radius to allow JR East to use control curvature.

Parameter	Repeatability (Dynamic 1σ)	Reproducibility
Gauge	$\leq 0.5mm$	Mostly the same as East-i
Longitudinal level	$\leq 0.5mm$	Mostly the same as East-i
Lateral alignment	$\leq 0.5mm$	Mostly the same as East-i
Cross Level	$\leq 0.5mm$	Mostly the same as East-i
Twist 5m	$\leq 0.5mm$	Mostly the same as East-i

Track Materials Monitoring System

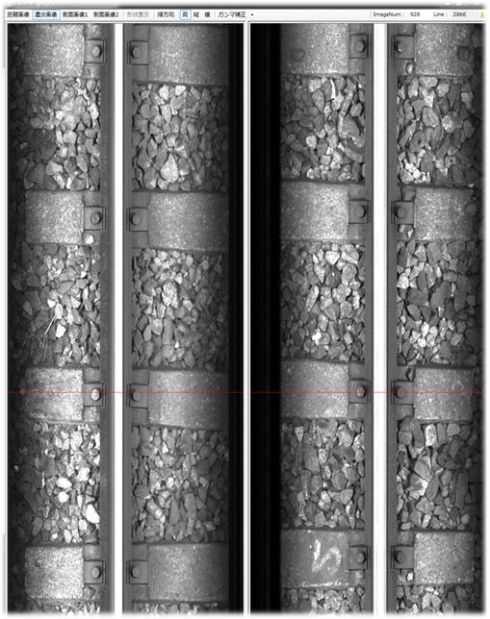
Monitoring Unit

720kg

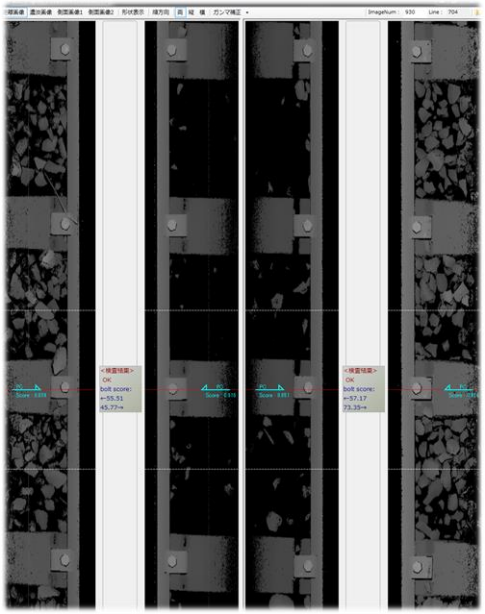
- The track materials monitoring system is equipped with 2 types of camera, which are line sensor cameras and range cameras all mounted in the same enclosure.
- The line sensor cameras are used for gray scale image recording, and the range cameras are arrayed to obtain information about elevation around rails.
- The outputs of range cameras will automatically show 2 types of defects which are missing of rail fastenings and fish plate bolts.
- It can identify in practical 3 types of errors which are fish plate cracking, electrical bonding falling, and insulation malfunctioning while checking grayscale images.

Track Materials Monitoring System

Gray scale image



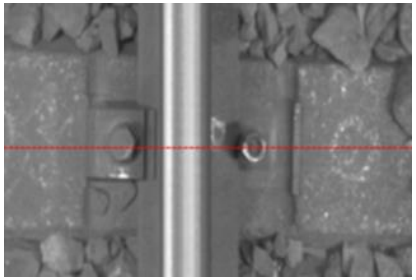
Range image



Verification of accuracy for fastening system

		Truth		Total
		Positive	Negative	
Result	Positive	133	65	198
	Negative	44	78,100	78,144
Total		177	78,165	78,342

TPR=99.92%



Example of false negative

Location Determination

- Both of the systems are designed to receive an input from Data Depot to allow the location determination to be estimated high accurately.
- The signal from a vehicle tachometer is also used for location determination and laser emission timing and shutter speed of the cameras.

DD memory

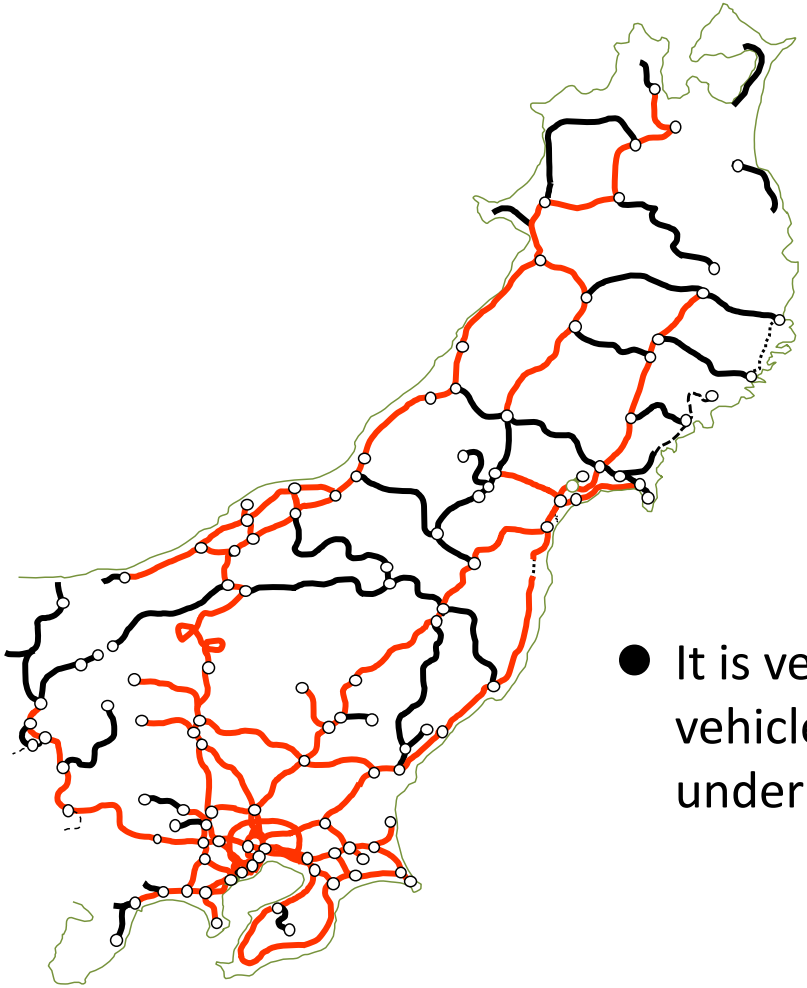
DD reader

The Data Depot System is a non-contact and high-speed digital identification system and consists of three items "DD Memory"(Data Depot), "DD Reader,“ and "DD Signal Processor."

Installation Plan

Policy

- All vehicles which have enough room mounted are to be installed.
- The number of installation is to be determined provided outputs will be acquired at least once a week.



Installation ratio=68%

Scheduled for installation

Unscheduled for installation

- It is very difficult to be placed on in-service vehicles such as diesel cars and locomotives underneath those due to space.

Issues

Frequency

- It is not evident that how many times we should measure tracks for CBM approach both from the point of view of a cost-effectiveness perspective and appropriate maintenance planning in practical.

Imaging analysis

- JR East's monitoring device automatically evaluates track defects regarding fastening systems and fish bolts. On the other hand, the other track materials have to be examined visually on the screen of the computers. We have been developing a technique for expanding the scope of automatic evaluation.

Downsizing

- We are not able to mount the devices to diesel car and locomotives because of the size. Some effort has been made to downsize the devices.

Decision Support for Track Engineers

Decision Support for Track Engineers

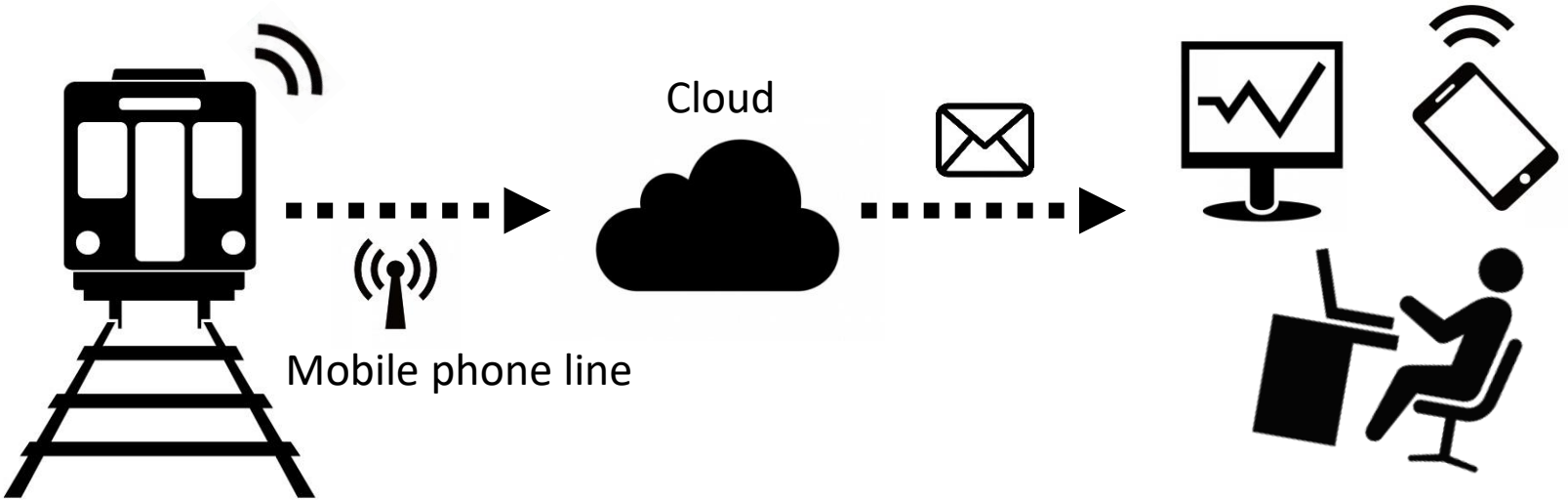
1. The systems will produce **exceedance alert** for any channel recorded. Every alert include the data regarding the value, the location, and the parameters by e-mail.

2. **Deterioration alert** about the sudden differences in track condition over time is under development. Overlaying two data sets allows differences in geometry to be calculated.

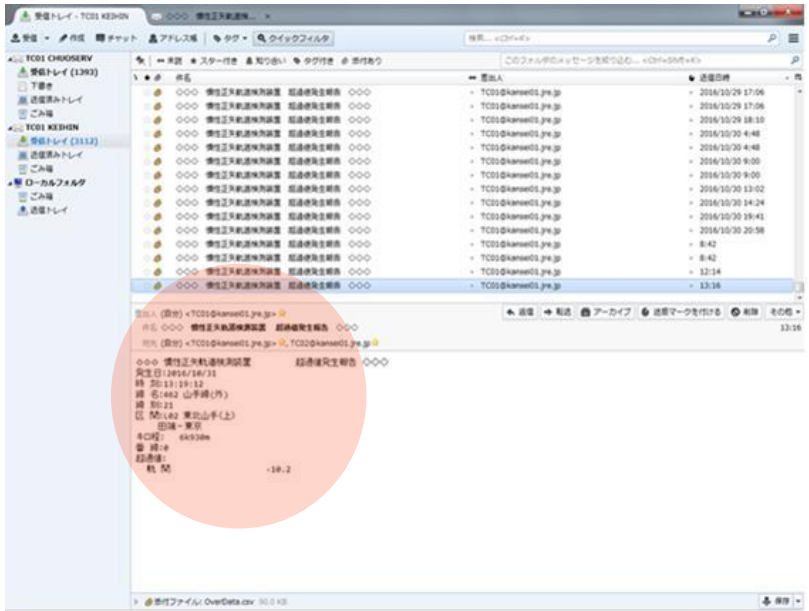
3. The systems will be used **to support track patrol**, which finds faults and identifies degrading track condition and will predict when the irregularities will become a failure.

4. Monitoring degradation of track would be useful **to evaluate maintenance work**. JR East has already assessed the work in high-speed lines so that some effort will be gone into realizing that in conventional lines.

Exceedance Alert



Screen Example



- Date of exceedance occurs
- Time of exceedance occurs
- Type of Parameter
- Name of line
- Inbound/Outbound
- Location
- Value of parameter

Deterioration Alert

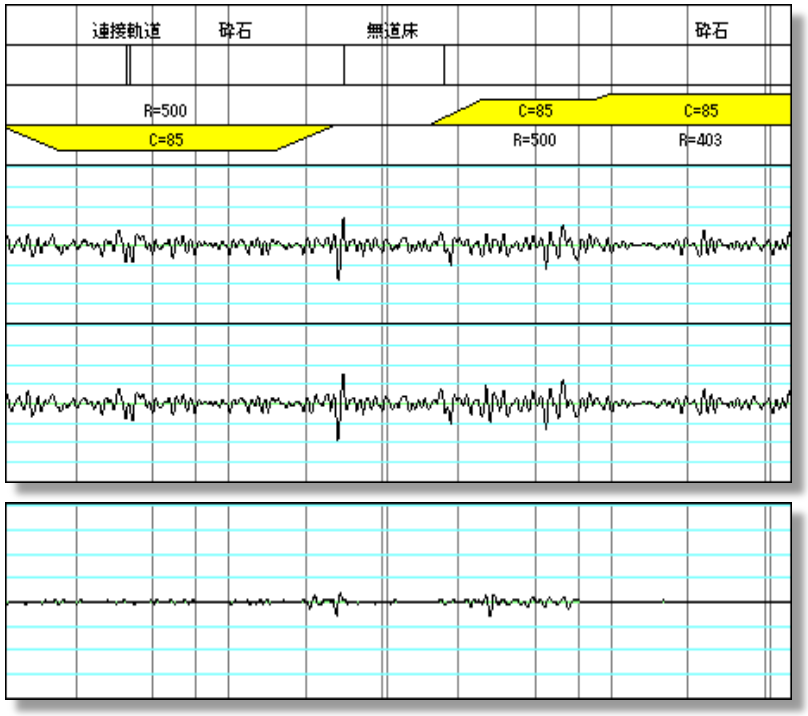
- It is very tough to ensure that the measuring vehicles will take measurements at the same locations every time over several consecutive measurement runs because a particular shift or location errors always occurs between consecutive measurements due to wheel slip, tachometer error, and high frequent noise.
- However, it is necessary to process measurement data into the analysis data to compare between several consecutive measurements as mutual alignment.
- JR East adopts cross-correlations method developed by RTRI to calculate differences in geometry. This allow track deterioration rate to be evaluated on waveforms overlaid 2 data sets for deterioration alert.

(1) Compared data

(2) The latest data

(3) Differences in geometry

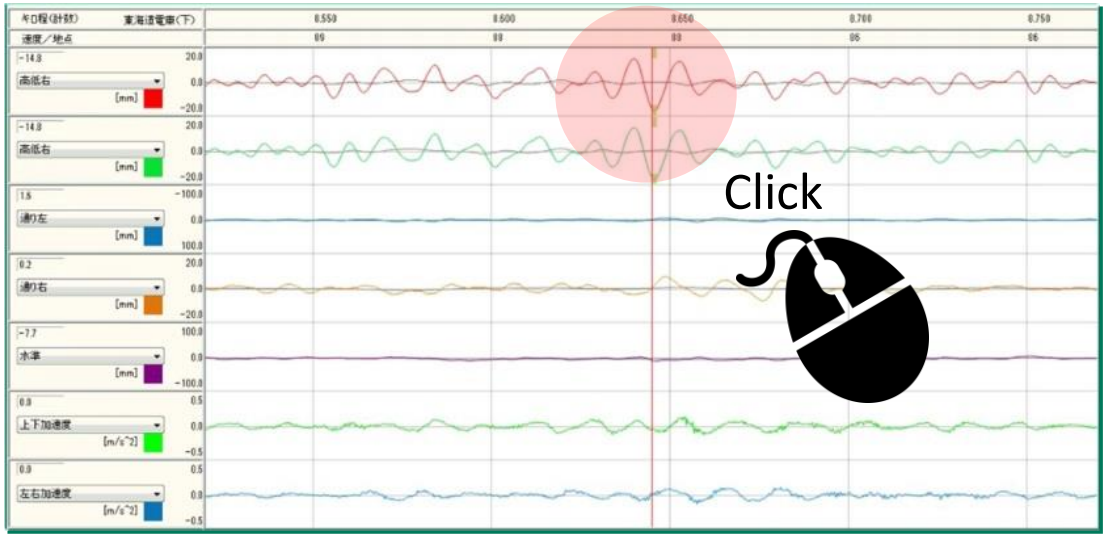
(3)=(2)-(1)



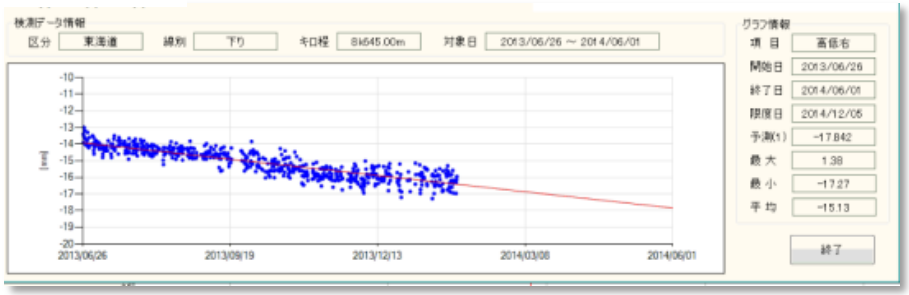
Track Patrol

- There is a need to develop models of how track degrade over time to make better predictions of the remaining life of rail track.
- JR East has developed a simple model, linear regression model, which is possible to predict when the track geometry exceeds thresholds at any location.

Track geometry

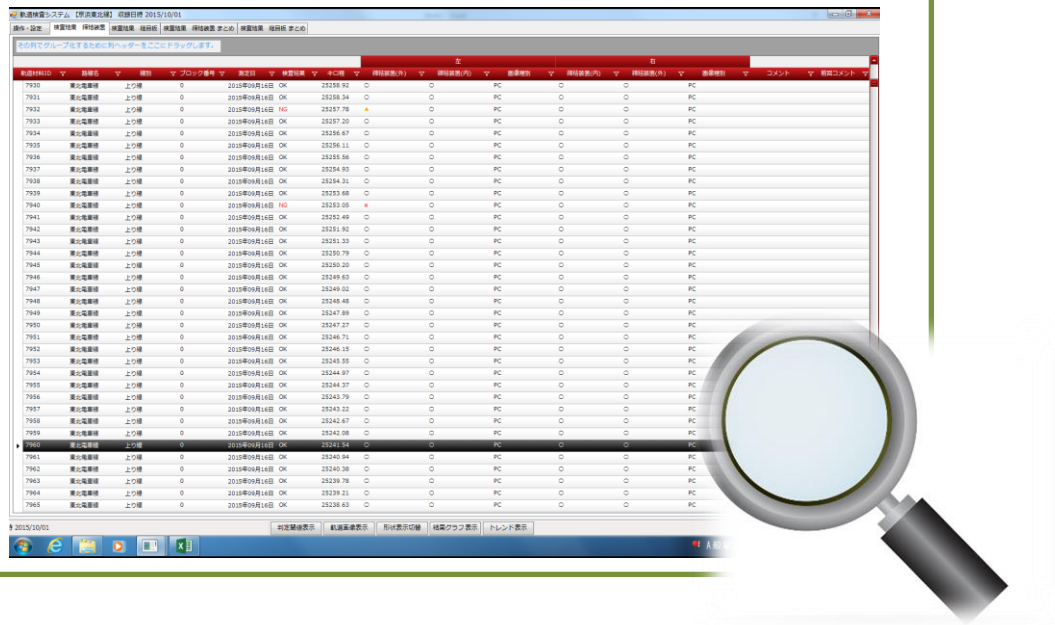


Linear regression



Track Patrol

Results of monitoring



- Each line represents the condition of each fastening system (every sleeper) described the location and evaluation.
- The following stand for the condition of fastening systems in this table.
  - ○: presence
  - ▲ :dubious presence
  - × :absence

Date of monitoring

Integrated result

軌道材料ID	路線名	線別	ブロック番号	測定日	検査結果
7930	東北電車線	上り線	0	2015年09月16日	OK

ID number

Computed results

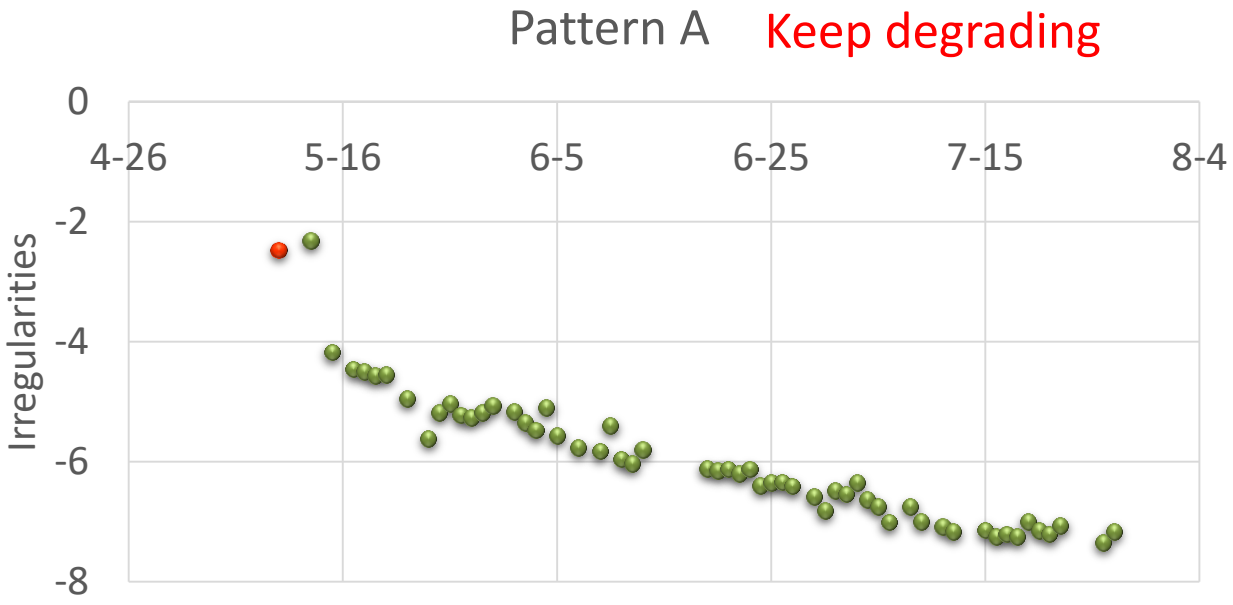
キロ程	締結装置(外)	締結装置(内)	画像種別
25258.92	○	○	PC

Location

Applications

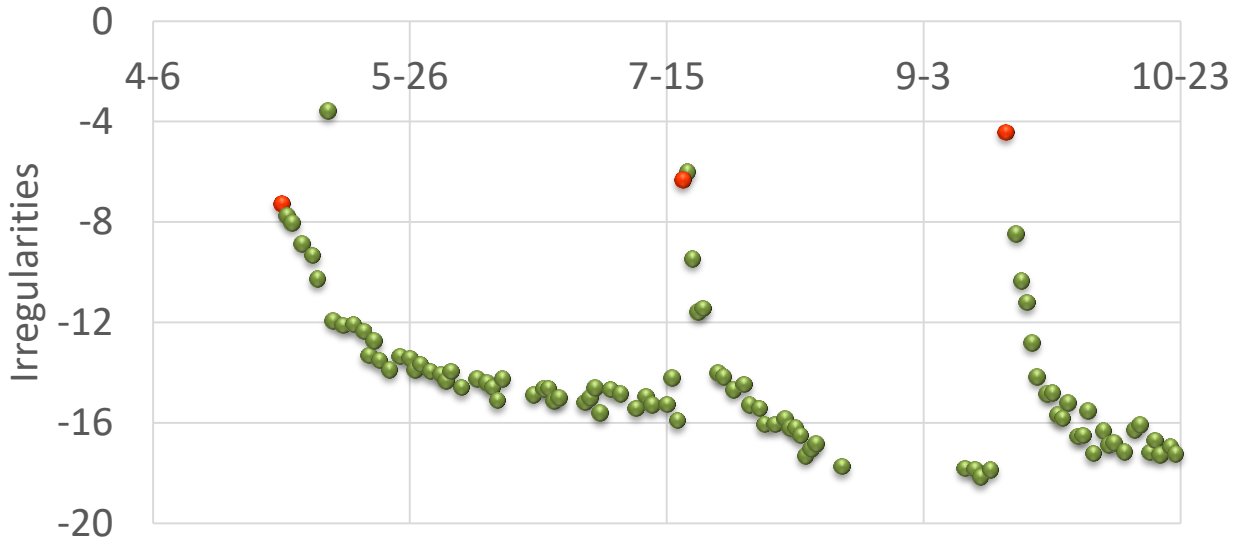
Track Irregularities

- The 65 repair works at an individual line near Tokyo was analyzed based on measurement data (Track engineers did not use these data at that time).
- It turned out that the deterioration of the tracks is classified to three types after interventions through this analysis. The first type is that tracks keep degrading over time. Next, tracks have suddenly gone bad and result in returning to an original condition in a short interval. The final classification is that maintenance action makes tracks stable despite initial degradation, which could reduce maintenance cost because of appropriate decision by track engineers.



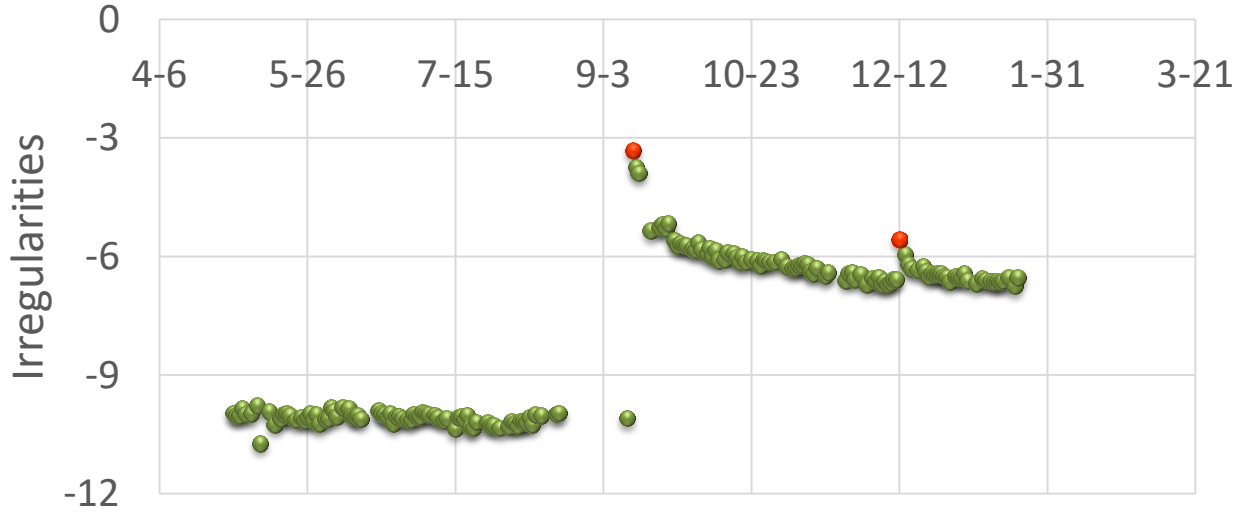
Track Irregularities

Pattern B Suddenly degrading



5/65=8%

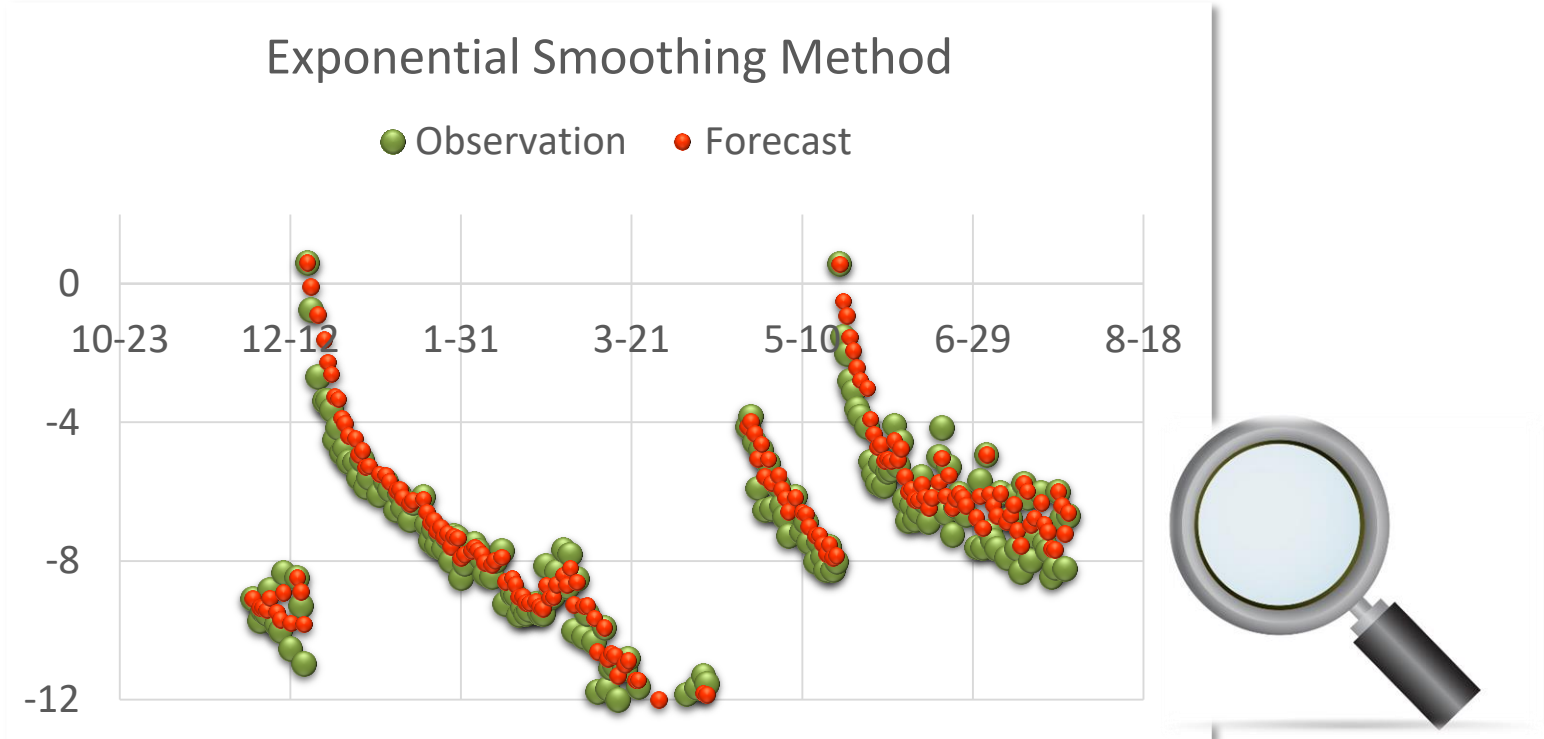
Pattern C Keep stabilizing



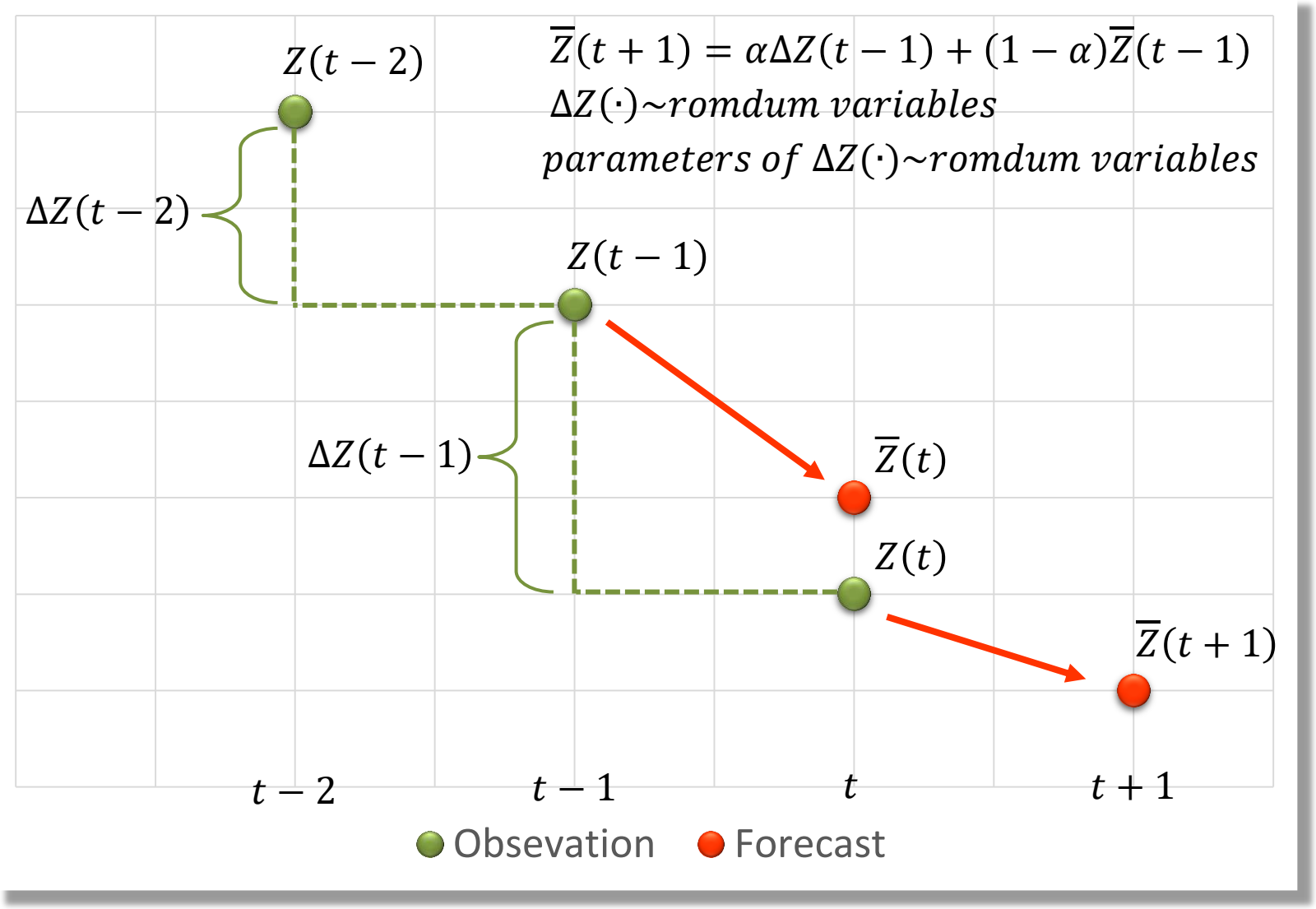
49/65=75%

Forecasting Track Irregularities by Bayesian Approach

- Track irregularities are the main factor that influences vehicle running stability and passenger riding comfortableness, so monitoring status of track irregularities in time is necessary to enhance railway services.
- Accurate forecasting the deterioration of track irregularities based on high frequent measurement data will be beneficial for track engineers because they will have to repair track irregularities within two weeks when the value exceed the predefined limitation.
- JR East and RTRI are developing the systems of forecasting track irregularities using Bayesian approach.

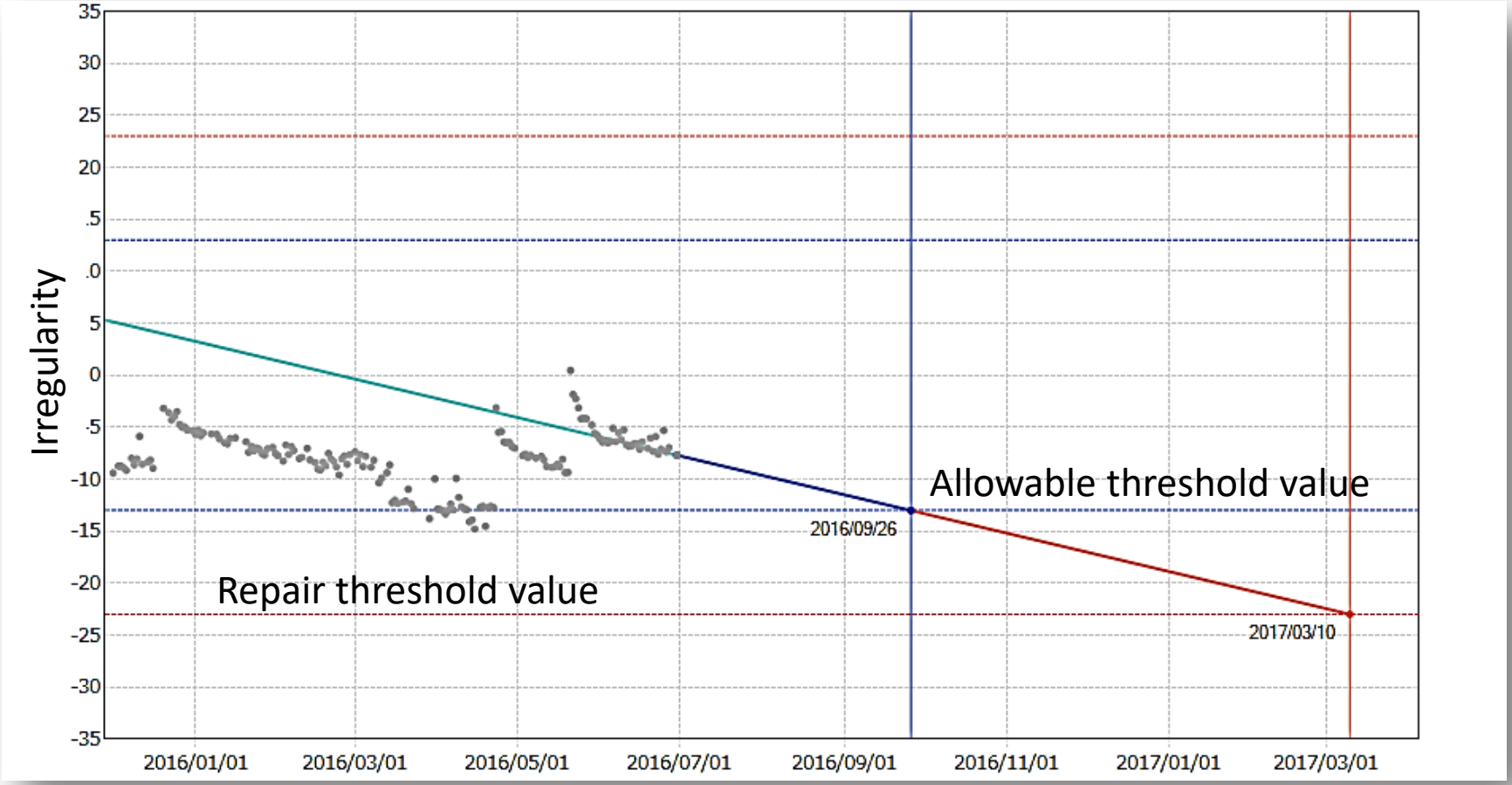


Forecasting Track Irregularities by Bayesian Approach

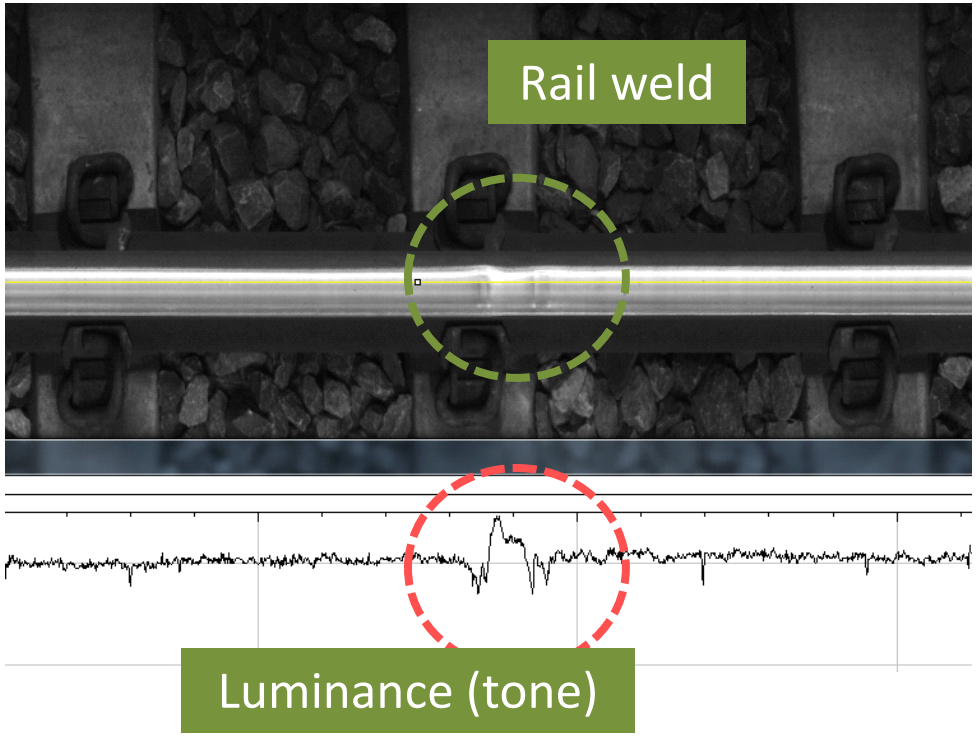


Forecasting Track Irregularities by Bayesian Approach

Computed Result on a Certain location



Rail Weld Irregularities

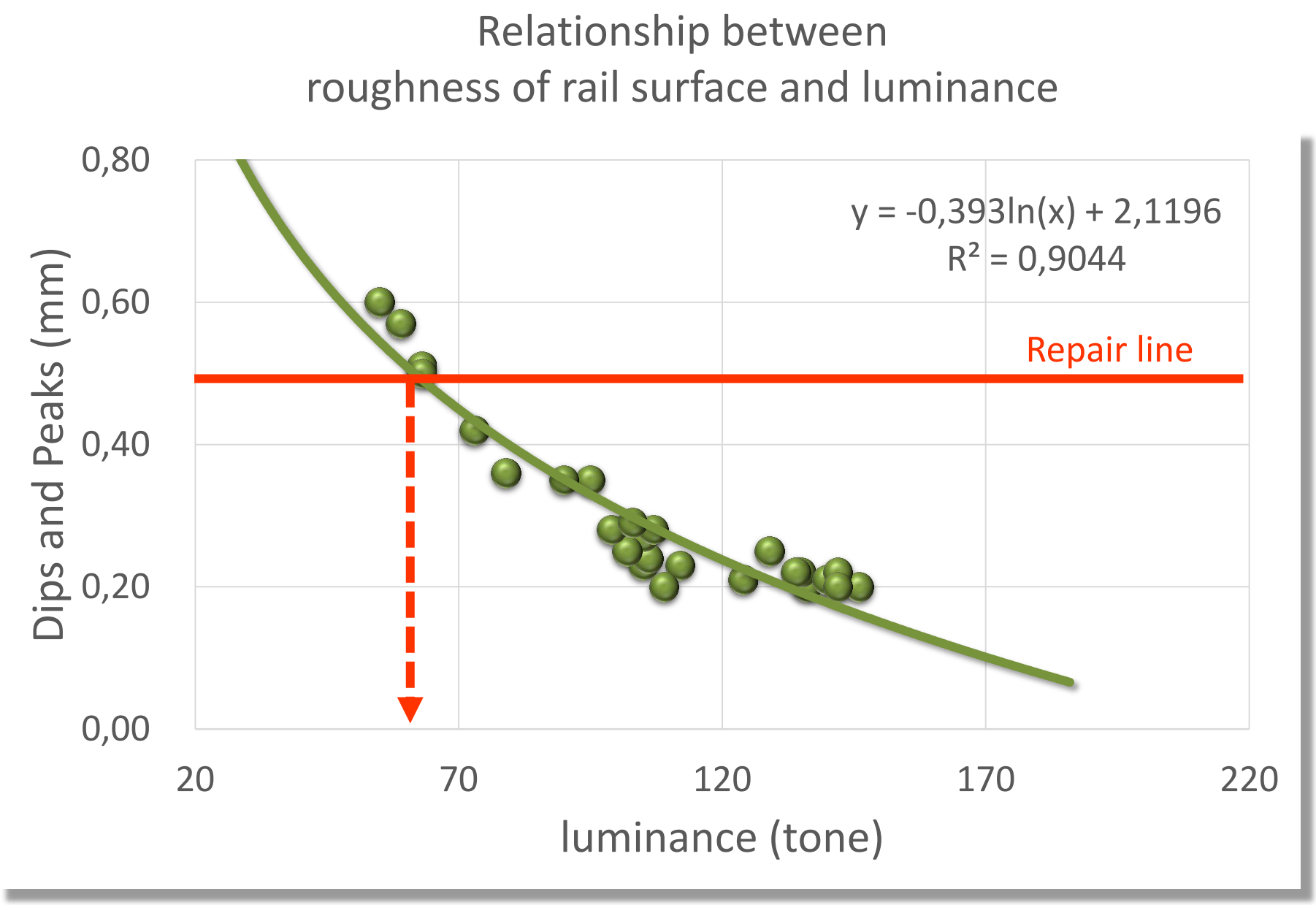


VS

Measurement of surface roughness

- Welds between sections of rails can become dipped or peaked due to high volumes of traffic causing a constant impact at welds.
- The roughness of rails surface such as dips and peaks will create a bouncing motion of vehicles leading to a poor passenger ride and a cracking of sleepers, breaking down in the ballast, finally losing track geometry.
- It results in a vicious circle if the defects are not removed.
- However, there are many welds in railway networks.
- It is significant that the defects which should be repaired are identified efficiently.

Rail Weld Irregularities



Summary

Points of Presentation

1. JR East decided to embark on the project to install 40 monitoring systems on in-service vehicles, which measure the tracks about 70% of the total. We have carried out R&D for the remaining 30%.
2. JR East developed the high-performance device to find out missing fastening systems and fish bolts. The R&D has been made for the other track materials.
3. A large quantity of data can be collected from the devices, but it is a challenging task to utilize information acquired from the data, which leads to a reduction of cost in practical terms.

Thank you for your attention

Tokyo Station