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Risk Analysis using Failure Data in Railway E&M System

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Abstract

In recent, the railway system consists of subsystems as rolling stock and infrastructures as signaling, telecommunication, power supply, overhead contact and platform screen door, etc. Furthermore, each subsystem has complicated interface so as not to understand these relationship. Consequently, to operate the railway system continuously with required safety and availability, the failure data should be corrected and analyzed systematically during operation. To achieve this object effectively, this paper presents the method which is evaluating the operational risk quantitatively using failure data, and selecting the critical equipment. Following this analysis, the improvement plan is established and applied to reduce the operational risk on system or equipment. From this study, the critical equipments of system could be determined and prioritized by risk analysis. Also, the effective maintenance to prevent critical failure could be implanted by this suggested methodology.

***Keywords* :** *Risk management, Railway System, Operation, Maintenance, RCM*

1. Introduction

Railway system consists of rolling stock and railway infrastructures that are interfaced with each other. In particular, in applying more sophisticated technology, it could not achieve the railway system to maintain with required safety and availability using existing management. To mitigate this problem, the systematic analysis is carried out in design and manufacturing stage before operation. However, the systematic analysis in operation stage was not executed before now. In this paper, the systematic analysis and management method in operation stage is presented for railway system, not limited on specific subsystem as rolling stock or signaling. Also, to achieve this effectively, the quantitative risk analysis method using failure data in operation is represented. Furthermore, the improvement plan on critical equipment was established to reduce the operational risk, and this was applied in maintenance.

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2. Procedure of Risk Analysis

2.1 Scope

In this study, the analysis was executed for E&M (Electrical and Mechanical) system that is affected to train operation directly. These are consists of rolling stock and infrastructure as signaling, telecommunication, power supply, overhead contact and platform screen door. The period for analysis was chosen to early year from opening.

2.2 Hierarchy of Items

The each items consisting of railway system are classified as subsystem and equipment with hierarchy. The example of hierarchy for rolling stock is shown as Table 1. Traction Motor in rolling stock consists of gear coupling, T/M Ass'y, stator, rotor and T/M speed sensor.

Table 1 Hierarchy of Rolling Stock Items

System	Subsystem	Equipment
Rolling Stock	Traction Motor	Gear Coupling T/M Ass'y Stator Rotor T/M Speed Sensor

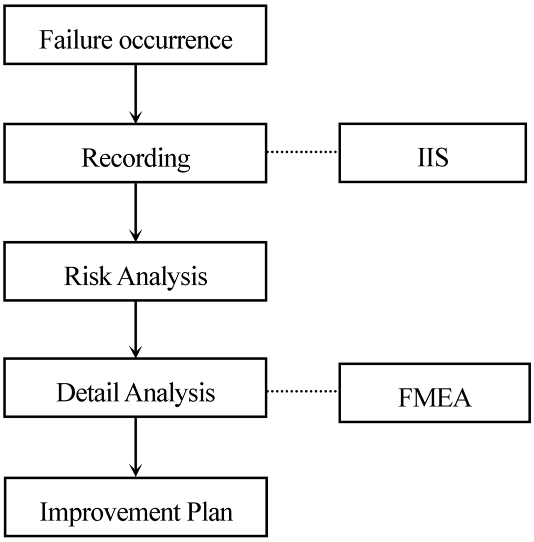

Fig. 1 Procedure of recording and analysis for failure

Table 2 Elements of Failure Code

Item code			Individual code		Common code			
System	Sub System	Equip.	Failure Mode	Failure Cause	Failure Effect	Failure Hazard	Failure Finding	Failure Correction

Table 3 Definition of Failure Effect

Failure Effect	Definition
Hazardous Failure	Failure to happen accident
Train delay Failure	Failure to happen train delay
Severe Failure	Failure to happen severe
Minor Failure	Failure to need minor corrective

2.3 Collection and Analysis of Failure Data

The data for failure during operation are recorded by IIS(Integrated Information System). The procedure of collection and analysis of failure data is shown as Fig. 1.

Table 4 Unit Severity Index of Failure Effect

Failure Effect	Symbol	Unit severity index
Hazardous Failure	A	50
Train delay Failure	B	10
Severe Failure	C	3
Minor Failure	D	1

In occurring failure in operation, the train driver or finder inputs the general information of failure to IIS. This information includes the occurring time, location and situation. And then, each failure data is analyzed with failure codes that are based on FMEA(Failure Mode and Effect Analysis). The failure code consists of ten elements shown as Table 2.

In analysis, each failure is classified with failure effect as hazardous failure, train delay failure, severe failure and minor failure. These are defined as Table 3.

2.4 Calculation of Risk Index

The risk analysis is based on the quantitative method considering severities and occurrence time of each failure effects in particular period. The unit severity corresponding with each failure effect is shown as Table 4. The unit severity index can be changed of weighting for operation condition.

The risk index for particular period is calculated as equation (1).

$$\text{Severity Index} = [A \times \alpha]+[B \times \beta]+[C \times \gamma]+[D \times \delta] \qquad (1)$$

where α: the number of times of Hazardous Failure(A), β: the number of times of Train delay Failure(B), γ: the number of times of Severe Failure(C), δ : the number of times of Minor Failure(D)

3. Case Study

3.1 Risk Analysis of Railway System

For the first step, the risk analysis for railway system

Table 5 Results of Risk Analysis for Whole System

Failure Effect	The number of times for each failure effect					
	RST	SIG	COM	PSS	OCS	PSD
Hazardous	0	0	0	0	0	0
Train delay	11	8	0	1	0	3
Severe	39	87	8	11	2	9
Minor	291	87	388	122	29	17
Risk Index	518	428	412	165	35	73
Order of Severity	1	2	3	4	6	5

Where RST: Rolling Stock, SIG: Signaling, COM: Telecommunication, PSS: Power Supply, OCS: Overhead contact, PSD: Platform Screen door

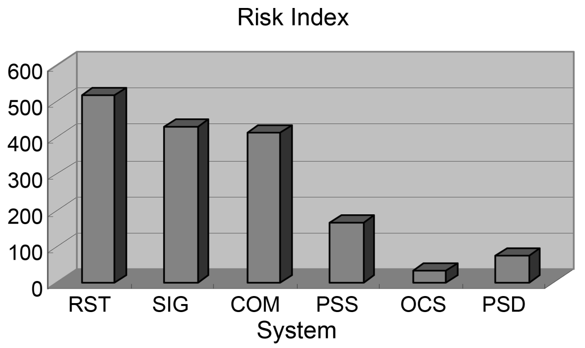

Fig. 2 Contribution of Risk Index for whole system

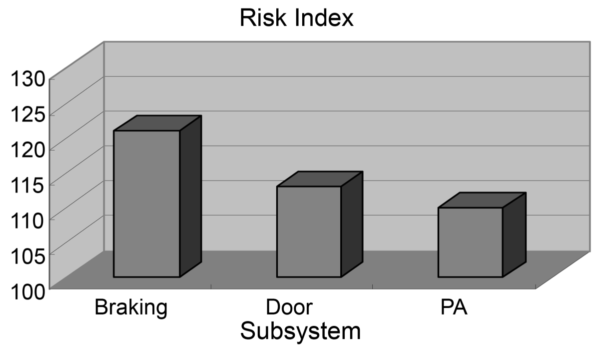

Fig. 3 Contribution of risk index for subsystem in RST

Table 6 Results of Risk Analysis for Subsystem

System	Order of Severity for subsystem (Risk Index)
RST	①Braking(121) ②Door(113) ③PA(110)
SIG	①Track Circuit(118) ②ATS(93) ③Onboard(91)
COM	①TRS(125) ②SCADA(102) ③PIS(36)
PSS	①Traction power(70) ②SCADA(59) ②General power(32)
PSD	①MOP(23) ②Sensor(19) ③Driving Unit(16)
OCS	①Wire(17) ②Structure(11) ③Equipment(7)

Where PA: Public Address, ATS: Automatic Train Supervisor, TRS: Trunked Radio System, SCADA: Supervisory Control And Data Acquisition, PIS: Public Information System, MOP: Manual Operation Panel

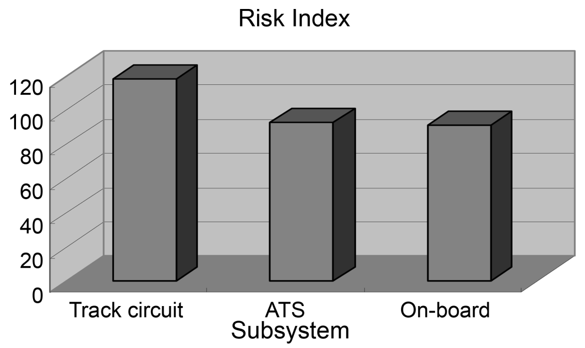

Fig. 4 Contribution of risk index for subsystem in SIG

was carried out. The results of risk analysis for whole system are shown as Table 5.

The priority of risk index for railway system is shown as Fig. 2.

As a result of risk analysis for whole system, rolling stock(RST) could give most critical effect to railway system's operation because it has the biggest value of risk index. Also, signaling(SIG) could give most critical effect to railway system's operation among infrastructure. Consequently, it was found that the order of severity was as RST, SIG, COM, PSS and PSD.

3.2 Risk Analysis of Subsystem

For the next step, the risk analysis for subsystem was carried out with previous method. The result of analysis is shown as Table 6.

The contribution of risk index for subsystem in rolling stock is shown as Fig. 3. As a result of risk analysis for subsystem, the braking could give most critical effect to rolling stock's operation because it has the biggest value of risk index. It means that failure of braking could give most critical effect to train delay.

Also, the track circuit in signaling could give most critical effect to railway system's operation. The contribution of risk index for subsystem in signaling is shown as Fig. 4.

3.3 Detail Analysis of Critical Items

From the risk analysis in previous, it was found that the braking was most critical subsystem in RST, and track circuit was most critical subsystem in SIG.

For the next step, the detail analysis for these most critical subsystems was carried out.

In detail analysis, the failure modes and failure causes for each most critical subsystem were extracted from failure codes. The result of detail analysis for braking is shown as Table 7.

Table 7 Results of Detail Analysis for Braking

Subsystem	Failure Mode	Failure Cause
Braking	Abnormal pressure	· Malfunction of sensor
		· Malfunction of relay valve
		· Malfunction of ECU
	Malfunction of brake releasing	· Malfunction of emergency electronic valve
		· Malfunction of brake cylinder

Where ECU: Electronic Control Unit

Table 8 Results of Detail Analysis for Track Circuit

Subsystem	Failure Mode	Failure Cause
Track circuit	Faulty of track occupancy	· Malfunction of Tx/Rx level
		· Breakdown of Bond line
		· Malfunction of Relay
		· Malfunction of PCB

Where Tx/Rx: Transmission/Reception, PCB: Printed Circuit Board

Table 9 Improvement Plan for Braking

Subsystem	Improvement plan	Category
Braking	Design review by manufacturer for malfunction of sensor	Design
	Design enhancement of durability for lead line of emergency electronic valve	Design
	Enforcement of quality inspection for inventory parts	Maintenance

Table 10 Improvement Plan for Track Circuit

Subsystem	Improvement plan	Category
Track circuit	Shortening of checking interval for Tx/Rx level (Monthly to Weekly)	Maintenance
	Enforcement of welding for bond lines at weak positions	Maintenance
	Shortening of checking interval for critical PCBs (Monthly to Weekly)	Maintenance

Also, The result of detail analysis for track circuit is shown as Table 8.

3.4 Improvement Plan

From the detail analysis in previous, the failure modes and failure causes for braking and track circuit were analyzed. For the next step, the improvement plan for these detail analysis was established. This plan was extracted from technical discussion with maintenance staff. The improvement was considered in respect of design, operation and maintenance.

The improvement plan for braking is shown as Table 9.

The improvement plan for track circuit is shown as Table 10.

4. Conclusion

This paper suggested that quantitative risk analysis from failure data during operation of railway system. This result was based on the operation data in early year from opening. The risk analysis was carried out for railway E&M system which is effecting to train operation directly. From this analysis, we found that followings.

1) From risk analysis, rolling stock gave most critical effect to railway system's operation as we expected. Also, signaling gave most critical effect to railway system's operation among infrastructure. The severity to railway operation could be arranged by risk index quantitatively. Also, the critical subsystems in each system could be determined by risk analysis for critical system. The braking gave most critical effect to train operation. Also, the track circuit gave most critical effect to signaling operation among infrastructure. The severity to railway operation could be prioritized by risk index quantitatively.

2) From detail analysis for critical subsystem, the major failure modes and causes were extracted from failure codes. Finally, the improvement plan for these critical failures was established from discussion with maintenance staff. In consequent, some design changes by manufacturer were required to stabilize train operation in early stage. Also, some reinforcements of maintenance were required to maintain stably for signaling.

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