A Study of Evaluation Methods for Railway Signalling Systems from the Viewpoint of Availability

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High levels of safety are required for railway signalling systems, for which various measures based on the fail-safe concept are taken to prevent failures because any failure has the potential to cause a serious accident. An International Standard, IEC 62278, has been instituted recently to view the reliability (R), availability (A), maintainability (M) and safety (S) of railway signalling systems. In some cases, it was necessary to analyze and evaluate the signalling systems from the viewpoint of availability, in addition to safety, which is the most important matter for consideration. For this reason the Railway Technical Research Institute (RTRI) is studying a method to improve the availability of signalling systems, while maintaining safety standards at the same level or even improving them (Table 1).

This method characteristically evaluates the measures needed to attain the target availability in terms of reducing the frequency of failure occurrence and cutting downtime of the signalling systems. For the purpose of this study, the author transforms the equation (1) that defines the availability of a system into the equation (2), considering that the frequency of failure occurrence λ per unit time is equal to the reciprocal of the mean time between failures (MTBF). Note also that the frequency of failure occurrence (λ) is in inverse proportion to the downtime of the system (MTTR) when availability remains unchanged.

$$A=\frac{\mathrm{MTBF}}{\mathrm{MTBF}+\mathrm{MTTR}} \quad \cdots\cdots(1)$$

$$\lambda=\frac{1-A}{A}\cdot\frac{1}{\mathrm{MTTR}} \quad \cdots\cdots(2)$$

The equation (2) indicates that there are two ways of attaining the target availability; one is to reduce the frequency of failure occurrence and the other is to cut the downtime of the signalling systems. These equations clarify that the purpose of the measures to be taken is to reduce the frequency of failure occurrences or to cut the downtime of the systems.

To validate the effectiveness of this method, the author carried out a case study of a railway line section around 50km long, with 15 stations equipped with interlocking, and operated by 101 trains per hour during peak hours on quadruple track at a typical station. The failure data used is based on the railway safety database which is managed by the Railway Technology Promotion Center, RTRI, and the period for analysis is about 5 years. The author set the target availability based on the decrease in the number of passengers affected by system failures, which is assumed to be proportional to the length of downtime.

Figure 1 shows the availability of system components of the line, in which the y-axis represents the frequency of failure occurrence and the x-axis the average maximum delay of affected trains, which corresponds to the downtime. The availability is higher for the components in the bottom left area in Fig. 1 and lower for those in the top right area. The three curves in Fig. 1, from left to right, indicate that the availability is 99.999%, 99.99% and 99.98%, respectively. The points marked in Fig. 1 indicate the values of availability of different components installed along the line. More specifically, availability is worst with level crossings, but it is better with interlocking devices, track circuits, cables between stations and point machines. As this evaluation aims to improve railway signalling systems, the author excluded from the analysis failures due to external disturbances or unknown causes and selected interlocking devices and point machines as the key components in this study.

In choosing measures to be taken for the selected components, the author assumes that a longer component vector of improvement in availability results in a smaller number of measures needed to achieve the improvement efficiently. As a best option for interlocking devices and point machines for example, the author selected two measures: "simplification of wiring" for interlocking devices and "enhancement of status monitoring" for point machines (Fig. 2). A combination of these two measures enables availability of about 99.92% to be attained efficiently, as indicated by the bold arrow mark in Fig. 2. In this manner, measures can be selected to efficiently attain the target availability for railway signalling systems as a whole.

The author will apply the above technique to other lines in the future and will propose measures to effectively improve railway signalling systems.

Table 1 Procedures to evaluate railway signalling systems from the viewpoint of availability

【Step 1】 Current status evaluation	【Step 2】 Setting of target values	【Step 3】 Determination of measures to be applied to attain the target availability
• Current availability (frequency of failure occurrence, downtime)	• Target availability	• Selection of target components for improvement and their effectiveness • Shortening the downtime • Improvement of reliability (decrease in the frequency of failure occurrence) • Improvement of maintainability (decrease in the frequency of failure occurrence) (by improved precision of detection)
• Effect on the current train schedule (number of trains cancelled or delayed)	• Target number of trains cancelled or delayed	• Effectiveness from the viewpoint of a whole signalling system • Frequency of failure occurrence after improvements • Downtime after improvements
• Current cost	• Target cost	

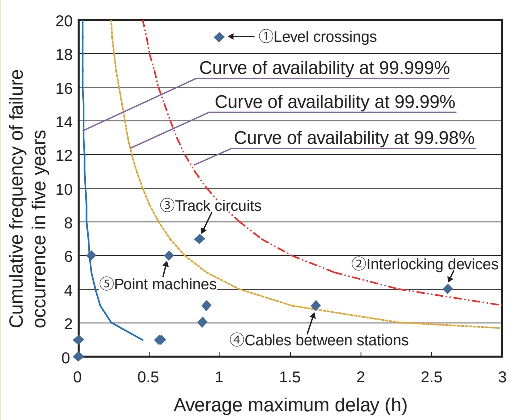

Fig. 1 Availability of system components

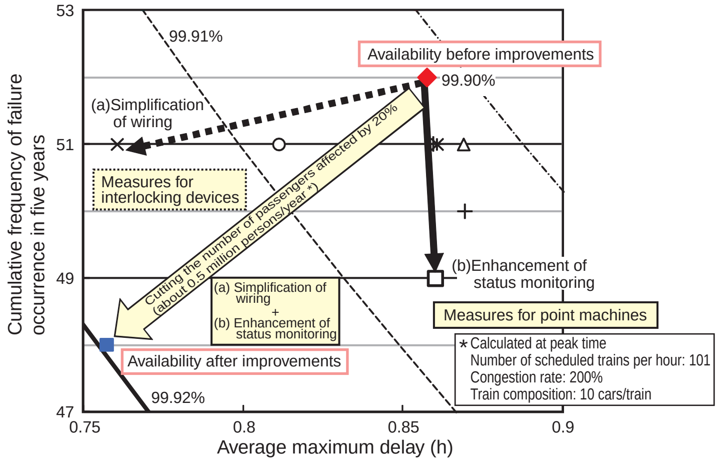

Fig. 2 Study of the application of combined measures to more than one component (Combination of measures for point machines and interlocking devices)