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Analysis of Reliability and Availability Indicators in Railway Vehicle Ordering Specifications of the Operating Agencies of Various Countries

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Abstract

Recently, the railway industry has been changing from small-scale and large many kinds of products structure to large-scale and fewer kinds of products structure. Therefore, it is necessary to study the standardization of railway components in order to establish reasonable maintenance systems. In this study, reliability indicators were analyzed in railway vehicle ordering specifications for the suggestion of guidelines for certification of railway vehicle components and reliability management system. In terms of reliability indices, Korean operating agency applies the concept of MKBSF 40,000 [Train-km] but Italy and Greece apply that MDBF and MDBCF and MDBF must achieve 160,000 [Train-km] per unit. In availability, there were differences between Korea and other countries. In Korea, which emphasizes service, the formula applying the concept of service failure time was used. On the other hand, Italy and Greece applied the same formula. The concept of service breakdown was confirmed to be used by all countries in common use.

Keywords: *Reliability, Availability, MKBSF, MDBF, MDBCF*

1. Introduction

The railway industry is one of the efficient and high mobility transportation through the development of railway technologies. In order to growing the railway vehicle parts industry, economy level of scale must be secured to develop or protect the technology. The recent trend is changing from small-scale and large many kinds of products structure to large-scale and fewer kinds of products structure. Therefore, it is necessary to study the standardization of railway components in order to establish a reasonable maintenance system for entering the international maintenance market. In this study, reliability indicators were analyzed in railway vehicle ordering specifications for the suggestion of guidelines for certification of railway vehicle components and reliability management system. Railway vehicle ordering specifications of Korea, Naples and Athens were analyzed.

2. Railway RAMS management system guidelines factor

RAMS stands for Reliability, Availability, Maintainability, and Safety. RAMS analysis is the work performed from the initial concept of the system to be developed to the disposal in the entire life cycle. Design, test and operational data are collected and analyzed during the life cycle. Database is made through this work. Through this, work such as design, evaluation, improvement of design, development of measures and analysis of supporting factors are supported. As shown in Figure 1, the RAM task is composed of configuration management (CM), human factor engineering (HFE), logistics support analysis (LSA), cost and operational effectiveness analysis (COEA), and Integrated Logistics Support (ILS).

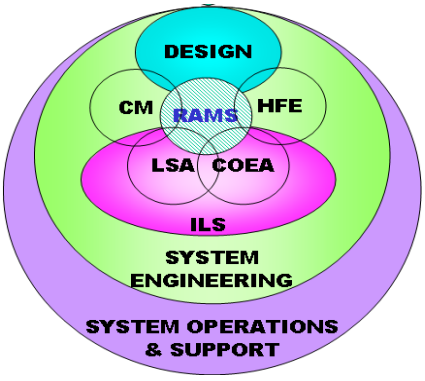

Fig. 1 RAMS Work Area

It started with the task of minimizing the failure of the equipment and improving the usability of the equipment by shortening the maintenance time in the event of a failure. In this study, reliability and availability closely related to maintenance were analyzed first.

3. Analysis of reliability indicators railway vehicle ordering specifications

3.1 Korean operating agency railway vehicle ordering specifications

The level of MKBSF (Mean Kilometer Between Service Failure) of a modular element of the train must not be less than 40,000 [train-km]. In addition, a Reliability Development/Growth test should be conducted and the results of this test should be included in the Reliability Report to demonstrate the steady increase in MKBSF. There are three types of faults classified into service faults, not found fault, and non-fault. Table 1 shows the classification of faults.

Table 1: Types of Faults

Types of Faults	Contents
Service faults	- Due to a car breakdown, the train is delayed by more than 10 minutes - Withdrawal of scheduled business operation due to vehicle failure except maintenance failure - Replacement of parts at service line due to failure during business operation
Not found fault	- When the fault is repaired, there is no symptom of failure
Non-fault	- Vehicle failure or accumulated vehicle delay caused by other vehicles or external influences - A vehicle failure that caused delays in several vehicles is calculated as one - Train delays or failures caused by business operating in an unusual condition (Train Diagram) - Failure due to non-compliance with operating instructions or maintenance instructions

3.2 Italian operating agency railway vehicle ordering specifications

Reliability goals in Italy is divided by the MDBF (Mean Distance Between Failures) and MDBCF (Mean Distance Between Component Failures). The level of MDBF of a modular element of the train must not be less than 160,000 [train-km]. The value of the MDBF of element is defined as the ratio between the distance accumulated by the whole population of identical elements and the total number of relevant failures that determine a failure on the train in operation. A malfunction of a train or a modular element of its composition is called a relevant failure. Table 2 shows the train failure.

Table 2: Train failure in Italy

When a train failure occurs
on its occurrence, it causes a delay to the final destination of more than 5 minutes
on its occurrence, it causes the removal from service and the immediate return to depot of a train in passenger service due to a reduction in the level of safety below the minimum permissible by the operating regulations and the rules in force in the field of rail transport
on its occurrence, it causes the continuation of the commercial route to the last stop and the subsequent return of the train to the depot as empty stock
on its occurrence, it causes the cancellation of the train and the commercial routes provided after a failure observed in the phases of activation and first test for entry into service
on its occurrence, the train is not capable of traction and is forced to request assistance from another train for return to the depot

MDBCF of the main systems and components of the train must not be less than the following values. In the design phase, the supplier will complement the table above with the target values for the remaining subsystems and components, while complying with the above values.
The MDBCF of an element is defined as the total operating mileage reached by the total population of

identical elements divided by the number of significant failure events that occurred in this population. The spare parts forming part of the "consumables" are excluded, unless they have not yet reached their useful design life.
Also excluded are failures in a system that are directly attributable to a primary failure and those due to a lack of maintenance by the client, vandalism or misuse, accidents or weather conditions considered to be abnormally severe.

Table 3: MDBCF of systems / equipment and subcomponents in Italy

System	MDBCF [km]
Body and chassis	250,000
Intercoms	100,000
Car	15,000
Automatic coupler	200,000
Door system and its associated command and control system	15,000
Passenger compartment air conditioning system	30,000
Braking system	17,500
Motor system	24,000
Auxiliary power system	30,000
Onboard information system (excluding radio system) and safety systems	26,000
System for Diagnosis, Management and Control of the Train (SCADA)	25,000

3.3 Greek operating agency railway vehicle ordering specifications

The reliability goal of Greece is divided into MDBF and MDBCF as in Italy. The level of MDBF of a modular element of the train must not be less than 160,000 [train-km]. The definition of train failure is the same as the Italian vehicle ordering specification. MDBCF of the main systems and components of the train must not be less than the following values (km).

Table 4: MDBCF of systems / equipment and subcomponents in Greece

System	MDBCF [km]
Complete Train	2,600
Car Body	175,000
Gangway	100,000
Bogie	50,000
Automatic coupler	200,000
Door System and Controls (including interlocks and signals)	15,000
HVAC - Passenger Compartment Air Conditioning System	30,000
Friction Brake Equipment	17,500
Propulsion System	24,000
Auxiliary Power Supply System	30,000
Communications and Passenger Information System (except Radio System) and Safety System	26,000
Train control and Management System	25,000

4. Analysis of availability indicators railway vehicle ordering specifications

4.1 The ability of Korean operating agency railway vehicle ordering specifications

Availability is a probability value that can perform a planned service at any given time. In Korea, the concept of vehicle service breakdown is applied. In Korea, the concept of vehicle service failure is applied. Equation 1 is an availability A formula applied to the Korean railway vehicle ordering specification.

$$A = \frac{T_{Total} - T_{Failure}}{T_{Total}} \quad (1)$$

Where, T_{Total} : Total operating time scheduled for the entire vehicle

$T_{Failure}$: Vehicle service failure maintenance time

A vehicle service failure means a failure that fails to perform the planned service of the vehicle. Availability is the correlation of vehicle reliability and maintainability. Therefore, the availability should be maximized by ensuring sufficient reliability and maintainability at the design stage. Vehicle availability should be at least 95% or more.

4.2 The availability of Italy and Greece operating agency railway vehicle ordering specifications

Operational organizations in Italy and Greece use the same availability formula. Availability is the probability that the trains are in condition to perform their intended service, assuming the required external resources are available. Equation 2 shows the equation of availability A.

$$A = t\alpha / ts = (ts - tc) / ts = 1 - (tc / ts) \quad (2)$$

Where, $t\alpha / ts$ = The total number of train-hours per day the scheduled fleet runs in revenue service
ts = The total number of train-hours per day the metro system is scheduled for service
tc = The total number of train-hours per day as a downtime required to repair the train due to train service failure

5. The analysis result of reliability and availability indicators in various countries

5.1 The analysis result of reliability indicators

Table 5 shows the reliability indices for each country. Korean operating agency applies the concept of MKBSF. This is because it considers the interruption of service of railway vehicle as the biggest risk factor. In Italy and Greece, the same reliability indicators are used and the figures are the same. One unit of railway vehicles must achieve 40,000 [Train-km]. In addition, MDBF and MDBCF are applied and MDBF must achieve 160,000 [Train-km] per unit. The MDBCF also depends on the part. This is because the components considered important by operating organization are different as shown in Tables 3 and 4. Although both MKBSF and MDBCF use a unit indicator, it is difficult to compare them because the concepts of failure are different.

Table 5: Reliability indicator by country

Country	Reliability indicator	Parameter value
Korea	MKBSF	40,000 [Train-km]
Italy	MDBF	160,000[Train-km]
	MDBCF	Depending on the part
Greece	MDBF	160,000[Train-km]
	MDBCF	Depending on the part

5.2 The analysis result of availability indicators

In availability, there were differences between Korea and other countries. In Korea, which emphasizes service, we used the formula applying the concept of service failure time. On the other hand, Italy and Greece applied the same formula. The concept of service breakdown was confirmed to be used by all countries in common use.

6. Conclusions

In this study, the reliability and availability indicators of vehicle ordering specifications were analyzed in various countries. Availability is based on a similar concept in ordering specification indicators of each country. On the other hand, the reliability indicators were found to be different according to the need of the operating organization and the concept of failure was also found to be different.

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