26th International Scientific Conference

October 5–7

TRANSPORT MEANS

2022

Proceedings

Part I

ISSN 1822-296 X (print)
ISSN 2351-7034 (on-line)

KAUNAS UNIVERSITY OF TECHNOLOGY
KLAIPĖDA UNIVERSITY
IFToMM NATIONAL COMMITTEE OF LITHUANIA
LITHUANIAN SOCIETY OF AUTOMOTIVE ENGINEERS
THE DIVISION OF TECHNICAL SCIENCES
OF LITHUANIAN ACADEMY OF SCIENCES
VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

TRANSPORT MEANS 2022

Sustainability: Research and Solutions

PROCEEDINGS OF THE 26th INTERNATIONAL SCIENTIFIC CONFERENCE

PART I

October 05-07 , 2022
Online Conference - Kaunas, Lithuania

KAUNAS•TECHNOLOGIJA•2022

CONFERENCE IS ORGANIZED BY
Kaunas University of Technology,
In cooperation with
Klaipeda University,
IFToMM National Committee of Lithuania,
Lithuanian Society of Automotive Engineers,
The Division of Technical Sciences of Lithuanian Academy of Sciences,
Vilnius Gediminas Technical University

The proceedings of the 26th International Scientific Conference Transport Means 2022 contain selected papers of 9 topics: Aviation, Automotive, Defence Technologies, Fuels and Combustion, Intelligent Transport Systems, Railway, Traffic, Transport Infrastructure and Logistics, Waterborne Transport.

All published papers are peer reviewed.

The style and language of authors were not corrected. Only minor editorial corrections may have been carried out by the publisher.

doi: 10.5755/e01.2351-7034.2022.P1

e.book, 2022

Proceedings of 26th International Scientific Conference. Transport Means 2022.

Decision-Making to Assess the Technical Condition of Locomotive Equipment in Conditions of Uncertainty

O. Krasheninin, O. Obozny, O. Shapatina, I. Kramchanin, O. Lagereva

Ukrainian State University of Railway Transport, Feuerbach Square 7, 61050, Kharkiv, Ukraine,
E-mail: oboznyj@kart.edu.ua

Abstract

Significant differences in determining the technical condition of locomotive equipment are due to a set of factors that determine it. The article considers the development of a formalized procedure for selection and decision-making in conditions of probabilistic uncertainty, which accompanies the change in the technical condition of equipment in conditions of uncertainty. According to statistics, the procedure for adopting a decisive rule for assessing the technology of control and repair measures to restore specific equipment is formed.

KEY WORDS: *decision-making, probabilistic uncertainty, degree of risk, faulty condition, probability of technical condition, maintenance*

1. Introduction

Repair facilities constantly face with the need to adjust the technological processes of service and maintenance of locomotive equipment.

The nature of this problem is the uneven use of locomotives, their age, operating conditions, branching and equipment of repair infrastructure, qualification of locomotive crews and repair specialists.

Recently, neither the locomotive fleet nor the repair facility has received new technical means for the operation, control and repair of locomotives. Outdated repair base, low production culture contributed to the decline of interest in the railway professions.

Foreign experience, on the other hand, shows a growing interest in the railway and its operation by potential workers. First of all, it concerns the rapid development of high-speed traffic, its comfort and accessibility, high earnings of specialists.

For domestic railway transport, there are tasks to increase the efficiency of railways by updating, modernizing and restructuring all branches of the industry.

This will be facilitated by the introduction of modern technologies and diagnostic and repair equipment in the repair industry.

At the level of public and sectoral management made a set of decisions aimed at updating the infrastructure of the railway industry [1, 2].

For a number of objective reasons, their implementation is slow [3, 4].

The locomotive industry has been in a state of stagnation for quite long time, which is facilitated by current events.

At the same time, abroad, the industry has long cooperated with science and educational institutions that train specialists for the industry and operation of locomotives [5].

In our country there is a great industrial potential and scientific schools that have invested and continue to make a great contribution to the development of the railway industry.

Thus, in [6] the theoretical provisions on the effectiveness of updating the TRS, taking into account the cost of life cycle. In research questions of efficiency of modernization of a rolling stock are considered.

In the conditions of aging of rolling stock scientific approaches on definition of system of the maintenance of locomotives at prolongation of term of their operation over normative are developed [7].

The purpose of the paper is to develop a decision-making procedure for assessing the technical condition of locomotive equipment in conditions of probabilistic uncertainty.

Accordingly, the following tasks are formed:

1. Determine the initial data for deciding on the technical condition of the equipment.
2. Formulate the procedure for selecting the necessary control technology for finished products.
3. Calculate the effectiveness of the right choice of solutions.

2. Presenting Main Material

In a competitive environment, any company has to solve a large number of problems with maximum efficiency.

Uncertainty of the components of the problem situation may lead to the need to make decisions from the standpoint of a systems approach. This usually requires research on the sequence of extraction levels of generalization, taking into account the complex relationships.

Any operation implemented within a system can be decomposed by both elements and processes.

The elements of operations are active resources, conditions and methods of its implementation. The processes that accompany the operation are targeted, leading to the target result, and functional, providing targeted processes, namely: the collection and processing of information, planning, management and control. The conclusions of the study are recommended for the implementation of decision-making.

Since operations are carried out under conditions of probabilistic uncertainty, the probability distribution of the set of vectors of characteristics of operations is matched to each strategy.

To establish rules on multiple strategies, the model of the operation objective must take into account the probabilistic nature of the operations.

Thus, problems of probabilistic solutions arise when the implementation of the operation significantly depends on the value of the uncertain factor.

Regarding the probability distribution of this factor at best, there is only preliminary information. Therefore, it is necessary to carry out a procedure to clarify this distribution. It is possible to conduct an experiment by determining some characteristics of operations z, the distribution of which depends on the value of the indeterminate factor λ.

Hence, the problem of probabilistic (statistical) decisions can be considered as a problem of decision-making regarding the conditions or results of the technical system based on the results of the study of its relatively simple subsystems (sub-operations).

Consider the following example. When performing the technological process, any product will be suitable with a probability of Pi. The product is made in batches of N pieces in each. A batch is considered suitable when it has no more than n_g defective products. It is assumed that the quality of products is controlled by checking randomly selected n products ($n < N$).

It is necessary to set the limit value z^0, on the basis of which the size of defective products z in the control sample of volume n should be considered with minimal risk to consider the whole batch in volume N suitable, ie which includes no more than n_g products.

In this case, the degree of risk associated with possible losses in production from the right or wrong decisions, and the amount of losses is an external complement to control operations.

The decisive rule can be two-alternative - only to accept or only not to accept the party, and multi-alternative - to accept, sending for processing or to carry out continuous control of all products, to reject. In the second case it is necessary to set not one limit z^0, but two – z^1, z^2. That is, when $z < z^1$, to accept the party, and when $z^1 > z^2$ – to reject, in other cases to carry out continuous control.

Thus, the problem can be formulated in the following statement.

The studied factor λ can take one of m possible values (states): $\lambda_1, \lambda_2, \ldots, \lambda_m$. A priori probabilities $P(\lambda_i), i = \overline{1,m}$ that satisfy the condition $\sum_{i=1}^{m} P(\lambda_i) = 1$.

A test is performed in which n independent observations of a certain characteristic (sign z of factor λ) are performed. The results of observations are represented by a system of random variables ($z_1, z_2, \ldots, z_n$) of discrete or continuous type due to the probabilistic nature of the factor λ.

The distribution of this system depends on the specific value of λ_i and is determined by the likelihood function $L(z_1, z_2, \ldots, z_n/\lambda_i)$, which is known for all $\lambda_i, i = \overline{1,m}$ and is given depending on the type of random variable z as follows. Thus, for a discrete random variable, it has a quantity:

$$L(z_1, z_2, \ldots, z_n/\lambda_i) = P(z_1, z_2, \ldots, z_n/\lambda_i) = \prod_{j=1}^{n} P(z_j/\lambda_i). \tag{1}$$

According to the results of the experiment ($z_1, z_2, \ldots, z_n$) it is necessary to choose one of K_0 solutions $x_1, x_2, \ldots, x_{K0}$, each of which is based on the assessment of the actual state λ_i.

The consequences of choosing any solution $x_{K_0}, K = \overline{1, K_0}$, provided that the choice is in the state λ_i, is characterized by the value of the loss function $\prod_{K_i} = \prod(x_{K_0}, \lambda_i)$, which characterizes the losses associated with the fact that the actual value λ_i of factor λ decision x_{K0} was made.

To establish the advantage over many strategies $U = \left[U_l, l = \overline{1, l_n}\right]$, the Bayesian function of efficiency of operations is used, which has the form:

$$W(x_K) = \sum_{i=1}^{m} \prod_{K_i} P(\lambda_i/z_n = g_k), \tag{2}$$

where $P(\lambda_i/z_n = g_k)$ - the a posteriori probability of the state λ_i, which corresponds to the fact that the sample z_n falls into the point g_k of the sample space z, $\prod_{K_i}$ - loss matrix.

As a criterion of efficiency the criterion of optimality is used in the form

$$x^* = \min_x W(x_K). \tag{3}$$

As an illustration, the calculation of the components included in the definition of decision-making strategy.

Let

P_i – the probability of suitability of the part (product);

N – the volume of the batch of products being tested;

n_g – the number of defective parts (products);

n – parts (products) taken at random ($n < N$);

z^0 – the threshold value that for z defects of products in the control sample n with minimal risk, the whole batch N is considered suitable.

If $z < z^0$ – accept the party;

If $z > z^0$ – reject the party.

Let $P_i = 0.5$; $N = 10$; $n_g = 5$; $n = 2$.

Loss matrix: $\left|\Pi_{K_i}\right| = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix}$.

The decision rule is as follows:

x_1 – accept the party;

x_2 – reject;

x_3 – carry out continuous control.

The status of the party is indicated as follows:

λ_1 – suitable;

λ_2 – unusable.

The space z has the form:

g_1 ($z = 0$) – the number of defective products in the control sample is zero;

g_2 ($z = 1$) – in the control sample there is one defective product;

g_3 ($z = 2$) – in the control sample there are two defective products.

Let's determine the a priori probability of the state of the party as follows:

$$P(\lambda_i) = P\left(n_g \le n_g\right), \tag{4}$$

where n_g – the random number of defective products.

Substitute the original data into this expression:

$$P(\lambda_1) = \sum_{i=0}^{n_g=5} C_{10}^i (1-P_i)^i P_i^{N-i} = C_{10}^0 (1-0,5)^0 0,5^{10} + C_{10}^1 (1-0,5)^1 0,5^9 + C_{10}^2 (1-0,5)^2 0,5^8 +$$

$$+ C_{10}^3 (1-0,5)^3 0,5^7 + C_{10}^4 (1-0,5)^4 0,5^6 + C_{10}^5 (1-0,5)^5 0,5^5 = 0,622;$$

$$P(\lambda_2) = 1 - P(\lambda_1) = 1 - 0,622 = 0,378.$$

To choose the strategy for deciding on the state of the product, we use the information Bayesian a posteriori rule.

To do this, we determine the a posteriori probability of the state λ_i, which corresponds to the fact that the sample z_n enters the point g_K of the sample space z.

$$P\left(\lambda_i / z_n = z\right) = \frac{P(\lambda_i) \cdot P\left(z_n = z / \lambda_i\right)}{\sum_{i=1}^{m} P(\lambda_i) P\left(z_n = z / \lambda_i\right)}. \tag{5}$$

Obtain probabilities $P\left(z_n = z / \lambda_i\right)$ by the conditional probability formula:

$$P\left(z_n = z/\lambda_1\right) = \frac{P\left(\hat{z} = z, n_g \le n_g\right)}{P(\lambda_1)} = \frac{\sum\limits_{j=1}^{n_g} P\left(z_n = z/n_g = j\right) \cdot P\left(n_g = j\right)}{P(\lambda_1)}, \quad z = 0,1,2; \tag{6}$$

$$P\left(z_n = z/\lambda_2\right) = \frac{\sum\limits_{j=n_g+1}^{N} P\left(z_n = z/n_g = j\right) \cdot P\left(n_g = j\right)}{P(\lambda_2)}, \quad z = 0,1,2. \tag{7}$$

To determine these components, we use the following expressions:

$$P\left(z_n = z/n_g = j\right) = \frac{C_j^z \cdot C_{N-j}^{n-z}}{C_N^n}, \quad j = 0,1,2,...,N; \quad z = 0,1,2; \tag{8}$$

$$P\left(n_g = j\right) = \mathrm{C}_N^j \left(1 - P_j\right)^j P_j^{N-j}, \quad j = 0,1,2,...,N. \tag{9}$$

Then the value of the efficiency indicator is determined as follows:

$$W\left(x_K\right) = \sum \prod_{i=1}^{m} {}_{Ki} \cdot P\left(\lambda_i / z_n = g_K\right). \tag{10}$$

At $z = 0$:

$$W\left(x_1\right) = \sum \prod_{i=1}^{m=2} {}_{Ki} \cdot P\left(\lambda_i / z_n = g_1\right) = \sum_{i=1}^{m} \prod {}_{Ki} \cdot P\left(\lambda_i / z_n = 0\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}899 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}15 = 1{,}5;$$

$$W\left(x_2\right) = \sum_{i=1}^{m=2} \prod {}_{2i} \cdot P\left(\lambda_i / z_n = 0\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}899 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}15 = 8{,}49;$$

$$W\left(x_3\right) = \sum_{i=1}^{m=2} \prod {}_{3i} \cdot P\left(\lambda_i / z_n = 0\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}899 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}15 = 4.$$

At $z = 1$:

$$W\left(x_1\right) = \sum_{i=1}^{m} \prod {}_{1i} \cdot P\left(\lambda_i / z_n = 1\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}6367 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}3632 = 3{,}63;$$

$$W\left(x_2\right) = \sum_{i=1}^{m=2} \prod {}_{2i} \cdot P\left(\lambda_i / z_n = 1\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}6367 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}3632 = 6{,}37;$$

$$W\left(x_3\right) = \sum_{i=1}^{m=2} \prod {}_{3i} \cdot P\left(\lambda_i / z_n = 1\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}6367 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}3632 = 4.$$

At $z = 2$:

$$W\left(x_1\right) = \sum_{i=1}^{m} \prod {}_{1i} \cdot P\left(\lambda_i / z_n = 2\right) = \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}315 + \begin{vmatrix} 0 & 10 \\ 10 & 0 \\ 4 & 4 \end{vmatrix} \cdot 0{,}636 = 6{,}36;$$

Proceedings of 26th International Scientific Conference Transport Means
ISSN 1822-296 X (print)
ISSN 2351- 7034 (online)

Design by Rasa Džiaugienė, Rolandas Makaras, Robertas Keršys
Cover Design by Publishing House “Technologija”

SL 344. 2022-10-26. 59.5 printer‘s sheets (Part I). Order No. 227.
Publishing House “Technologija”, Studentų 54, LT-51424, Kaunas

transportmeans.ktu.edu

ISSN 1822-296X (print)
ISSN 2351-7034 (online)