FORECASTING OF SAFETY TRANSPORT BY EXTREME STATISTICS

PROGNOZOWANIE BEZPIECZEŃSTWA OBIEKTÓW TRANSPORTOWYCH METODAMI STATYSTYKI EKSTREMALNEJ

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Abstract: *Recently, the transport problem is acute to minimize accidents and disasters, caused by the failure of the functional elements. Today it is still not a fully developed theory of the solution of such problems. The authors propose an approach to perform this task, based on the methodology of extreme statistics and information Janes principle. Example given in the article and the calculations prove this possibility, up to an extreme level of statistical sampling, when it reaches capacity. The method allows for a decision on a sample survey, when the nature of the distribution is not known anything other than the expectation of a random variable.*

Keywords: *security, transport, statistics, accident, method*

Streszczenie: *W ostatnim czasie w dziedzinie transportu pojawiło się pilne zadanie sprowadzenia do minimum występowania wypadków i katastrof, których przyczyną są awarie elementów funkcjonalnych. Obecnie jeszcze nie sformułowano rozwiniętej teorii rozwiązywania takich zadań. Autorzy proponują sposób rozwiązania postawionego zadania na podstawie metodologii statystyki ekstremalnej i zasady informacyjnej Jaynesa. Przedstawiony w artykule przykład i obliczenia dowodzą takiej możliwości, do ekstremalnego poziomu statystycznego wyboru włącznie. Metoda pozwala realizować podjęcie decyzji według wybranych obserwacji, gdy o charakterze podziału nie wiadomo nic oprócz wartości oczekiwanej wielkości losowej.*

Słowa kluczowe: *bezpieczeństwo, transport, statystyka, mała próbka, statystyka ekstremalna*

1 . Introduction

By the beginning of XXI century in the theory of reliability there were two scientific directions having the single mathematical apparatus of mathematical statistics, but different objects of the analysis: reliability of technical means and reliability of man-machine systems.

In the first case methods and solutions of reliability increase, operation efficiency and wear resistance of technical systems and elements, devices, widgets are considered. Search of decisions in information about condition of such objects quite reasonably is based on statistical selections, classical methods of the theory of probability.

Existing techniques of reliability increasing, scheduled preventive surveys for widgets (systems) of different function quite satisfies for tasks of forecasting of their safe operation.

Otherwise case is in the situation of man-machine systems. The final decision by an assessment and change of an object condition, its characteristics in the course of accomplishment of criterion function belongs to the person operator. Here the leading role is played by the current information received from devices and monitoring systems. Collection of statistics on the current information emergency (not standard) nature can't be almost provided by big massifs. Most often this information either is single, or belongs to the class of "small selections". Such provision entirely belongs to transport systems [1,7].

Statistical information on the incidents connected with transport objects, is limited and heterogeneous. Such events are, as a rule, single or seldom repeat. Therefore the safety assessment on transport is carried out at high-quality level as information for its quantitative assessment existing mathematical apparatus has absolutely not enough.

Therefore, the theoretical base is necessary for development of evaluation methods of reliability of objects in conditions of "small selections" and "single selections". These methods shall reflect specifics of operation of systems of the increased danger to which all mobile objects belong, but first of all – transport. Set of such methods we will determine the term "extreme statistics". Object of researches of extreme statistics are the information massifs constructed according to the statistics "small selections" and result – decision making methods, основанные on the analysis of single information.

2 . Information security of transport object

Railway vehicles, cargo handling machinery, elevators, etc. on technology of accomplishment of the tasks are objects of the increased danger. On transport classification of refusals is structured on nature of consequences:

- incident (catastrophic crash, accident);
- incident (the non-local refusals, fires, switching off of engines in the course of movement or maneuver, failures of aggregates and the systems which don't have duplications);
- forced interruption of movement (stopping, landing, drift).

However, the established reason of accidents and catastrophic crash on transport the last decades, is distributed absolutely unevenly [8]:

- 98% are carried on the person operator (the pilot, the navigator, the driver),
- 2% fall on technical means (refusal, defect).

The specified provision is quite explainable that technical devices process and implement information on the set algorithms and the programs, based on standard or earlier received statistical results. That's why the person is forced to make operational decisions in extreme conditions, making use of experience of own knowledge and intuition. Such decisions are based on information on refusals of technical means, including automatic equipment, or in case of an unforeseen situation. Therefore, the leading role in decisions of the operator is played by very limited information on the similar (similar) cases which have occurred earlier. At the same time, statistical information on incidents (accidents, catastrophic crashes) on transport is single even on the long periods measured on years. Therefore situation analysis and decision making should be carried out in the conditions of extremely limited information [5,6].

Exactly here the trust to justification of the percentage ratio of the reasons of accident rate stated above on transport is lost. It isn't difficult to see that if technical elements (engines, navigation devices, automatic complexes, fire means, etc.) are in working condition, information from them has static nature and doesn't demand from the operator special (not standard) decisions on change of characteristics of movement. Any acceptable deviations are identified and eliminated.

Absolutely other situation arises in case of refusal of these elements in the course of the movement, having consecutive or avalanche nature. Such information on a condition of object and its elements is accidental and the extremely rare, the standard algorithms of decisions pledged in automatic equipment, can't identify it as their models were based on big selections of possible refusals of elements and technical complexes. The obtained operational data appear on "the ends of statistical distributions". Models of such cases can be constructed only when using the statistical device based on extremely small number of events [1,4].

So there is a task of "information security" of transport object: with set confidential probability to give an assessment of border of a safe condition of an element (a complex, the device) in the course of its operation.

There are two directions of possible decisions:

- development of the methods is necessary for a quantitative assessment, giving the chance to determine reliability of elements by small number of supervision with required reliability;
- the methods which are adequately describing limiting areas of distributions on limited information are necessary for an interval assessment.

Determination "small selection" is so far debatable [1,5,7]. In literature its various interpretation meet: insignificant, small, extremely small, single, etc. Let's accept the $n = 30$ abroad between concepts "small" and "regular (big)" selection [6]. Authors consider as the basis for this statement result of comparison of

t - distribution with normal distribution. Even in the visual analysis of tabular values it is possible to notice that this approach becomes quite fast, beginning names with $n = 30$ and above [7]. Then we will accept selections in amount less than 30 supervision for "small".

The analysis of a condition of objects on small number of supervision are required not asymptotic methods based on extreme distributions. This direction in the decision making Theory still is still a little developed. Complexity of statement and the solution of tasks of the best estimates in case of small quantity of a statistical material depends on specific type of distribution, selection amount. The statistical material is created of rare data, characteristic for the extreme conditions meeting on transport. Here not really to receive the authentic decision by the classical method, based on limiting distributions. It is offered to solve this problem based on the information approach considering the principle of a maximum of uncertainty [3,4].

3 . Method of the statistical assessment of information security of object

Uncertainty of reasoned decisions in extreme situations of behavior of objects because of failures of their vital technical devices and complexes sets the task developments of imitation methods of an adequate assessment and forecasting of their condition. This conclusion is especially actual for transport systems. They containing in a basis of the work the moving objects, constituting the increased danger on nature of accomplishment of criterion function.

At the heart of such device must be the complex of the mathematical means having two main properties:

1. opportunity to operate with statistical information of accidental and single nature on refusals of objects,
2. most full to consider uncertainty of statistical data on reliability of elements (devices) when only the population mean of emergence of their refusals is known.

The most preferable in this case is the information approach using the principle of a maximum of uncertainty (the Jaynes principle), based on consideration of entropy of Shannon. This approach is least sensitive to initial assumptions and generally allows to consider any number of located information [6].

The principle of a maximum of uncertainty (entropy maximum) gives the grounds to consider that the greatest reliability probabilities which maximize uncertainty when accounting all acquired information will possess. Measure of uncertainty there is an entropy. Important difference of the principle of a maximum of uncertainty is possibility of receipt of estimates of aprioristic distribution in information situations for which various restrictions in the form of the probability measure, separate moment characteristics, etc. [7] are known. Thus, they can be provided in the form of equalities and inequalities. From the mathematical point of view, when using the principle of a maximum of uncertainty, the task of such restrictions leads to the solution of classical and non-classical tasks of optimization (tasks on extreme point).

The basis for carrying out the analysis were the empirical supervision connected with accidents of ocean and river crafts in 2010-2012 [8].

Let's consider empirical density of distributions of the smallest (extreme) value in the selections of various amount received by imitating modeling from population with the exponential distribution law, the most characteristic for transport systems [2]. Their smoothed type is provided on Fig. 1.

With increase in amount of selection, other things being equal, distribution of the smallest random variable is displaced to ordinate axis. As theoretical reasons for statement the following reasons serve. Generally, function of distribution of the smallest value in selection in amount looks like [5]:

$$F_{t_{\min}}(t_{\min}) = 1 - [1 - F(t_{\min})]^n \quad (1)$$

and density, respectively

$$f_{t_{\min}}(t_{\min}) = n[1 - F(t_{\min})]^{n-1} \cdot f(t_{\min}), \quad (2)$$

where: $F(\cdot)$ и $f(\cdot)$ – function and density of initial distribution.

Then distribution density of the smallest value in selection of exponential distributed population will be written as follows:

$$f_{t_{\min}}(t_{\min}) = n\lambda e^{-n\lambda t_{\min}}, \quad (3)$$

where: $\lambda = \frac{1}{T}$ – parameter of the distribution;

T – The expectation of a random variable t .

Physical sense of a formula (3) that the smallest value of selection is shown with the intensity which is pro rata to its amount. Distribution of the smallest value in selection, generally, the bilateral. However, in the conditions of a solved task us only the left border of expression which characterizes the smallest (extreme) random variable interests. Therefore we set

$$F(T_{\min}) = \frac{\alpha}{2} \quad (4)$$

Then the population mean of T of a random variable will become [6]:

$$\hat{T}_H = \frac{\alpha}{2} T, \quad (5)$$

Theoretical T_H value under the same conditions will be

$$T_H = 2T \left(1 - \sqrt{1 - \frac{\alpha}{2}} \right). \quad (6)$$

In Fig. 2 there is theoretical and asymptotic functions of quantiles of distribution of the smallest random variable from selection exponential - distributed general body.

In the same place it is shown their disparity, increased on 10 for descriptive reasons. It isn't difficult to see that the difference between theoretical and asymptotic values for selection of the minimum amount in almost used range doesn't exceed 3%. Experiment confirmed the sufficient accuracy of a method for an extreme case of amount of selection (Fig. 2).

Fig. 1. Empirical density of the smallest value in a sample t

Fig. 2. Charts and theoretical asymptotic function quantile

Thus, the analysis did not reveal the contradictions in the representation of quantile of order statistics in the form of asymptotic dependence (5) when a uniform law, the expression is of sufficient accuracy for practical approximates the relationship (3) in the range of the specified range.

4. Conclusions

For the purpose of safety of movement it is necessary trouble-free for operation both all elements of transport objects, and their systems. It is obvious that absolute elimination of such refusals not really.

Then means of minimization of accidents and catastrophic crashes on the transport which reason are refusals of functional elements, control and management systems are necessary.

This problem belongs to tasks of the Theory of reliability. But its fundamental difference from them that the statistics of refusals on transport belongs to tasks of "small" and "single" selections on long intervals of time.

The approach given in work based on methodology of Extreme statistics, proves basic opportunity solutions of the statistical selection set tasks up to extreme level when its amount reaches size.

Results of the offered method can be used also in case of reasons for safety requirements to technical elements, nodes, designs and control devices of railway vehicles in extreme conditions.

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