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TECHNICAL DECISIONS IN UNCERTAIN ENVIRONMENT AT RISK

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A model has been built for estimating the degree of uncertainty in making technical decisions. It is based on a comparison of the results of decisions made (training sample) with their assessment based on indicators adopted for the intended decision making.

Keywords: operational safety, risk minimization, uncertainty, decision making, training sample, replacement function, quantitative risk assessment.

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ПРИНЯТИЕ ТЕХНИЧЕСКИХ РЕШЕНИЙ В УСЛОВИЯХ НЕОПРЕДЕЛЕННОСТИ ПРИ НАЛИЧИИ РИСКА

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Построена модель оценивания степени неопределенности при принятии технических решений. Она основана на сравнении данных обучающей выборки с их оценкой по предлагаемым в модели показателям.

Ключевые слова: безопасность эксплуатации, минимизация риска, неопределенность, принятие решений, обучающая выборка, замещающая функция, количественная оценка риска.

Introduction. Nowadays in engineering practice, it is increasingly necessary to make decisions in uncertain environment, when the consequences of decisions are associated with a particular risk. The risks in this case include the possibility of accidents, catastrophes and other events defined by the concept of "operational safety". It is obvious that in making certain technical decisions in uncertain environment, the risk cannot be fully excepted. Informed risk-taking and its minimization should be taken into account in modern conditions, avoiding its complete disregard. Moreover, it may sometimes be beneficial not to minimize the risk but to allow some level of risk, especially in uncertain environment, in order to increase the overall usefulness of the decision. This is due to the fact that risk-free decision-making, for example, from an extremely pessimistic position with maximum caution, is usually unprofitable. In the scientific approach, the decision must be taken from the position of assessing the quantity of risk, which has a given boundary when achieving the result with the necessary certainty. The solutions described below are aimed at ensuring the effectiveness of technical decision-making in uncertain environment with a calculated risk.

The concept of risk and uncertainty. The technical decision taken in situations involving risk, in addition to the desired positive result, necessarily leads to any losses (financial, material, temporary, etc.). The cost depends on external conditions (effects), and this dependence is not probabilistic, but possible, especially with single decisions. In the field of engineering practice, the concept of risk has the meaning of "responsibility for the decision" [1]. And this responsibility is connected, first of all, with the life and health of people. In all cases, in accordance with the requirements of modern science, the concept of risk should make it possible to quantify it. In the future, the risk will be understood as the value that characterizes the possibility of obtaining an undesirable result in the considered situation of decision-making. In particular, in [1] it is proposed to determine the amount of risk as a product of the value of the undesirable result (or an event uniquely associated with this result) by the possible extent to achieve it (or the possible extent of the occurrence of the corresponding event). Therefore, to quantify the risk, let us first assume that each considered variant of the A_i decision from a finite set of variants $A_1, A_2, \ldots, A_i, \ldots, A_m$ is uniquely associated with some undesirable result depending on the external conditions (effects) of F_j. In general, in uncertain environment, the set of external conditions F is described by fuzzy set theory and is also finite, although it is principally possible to consider an infinite fuzzy set of external conditions $F_1, F_2, \ldots, F_j$. Next, we will consider the situation of decision-making, when considering obviously unacceptable options we will need to make a choice. We believe that the results contained in the set A will meet the conditions with a positive outcome. In this case, the problem of decision-making is to reduce the probability of large losses when choosing an alternative from the set A of the following form [2]:

$$A_i = (e_{i1}, p_{i1}; \ldots; e_{ij}, p_{ij}; \ldots),\ i = 1, 2, \ldots, m,$$

where e_{ij} is the loss that occurs when the j-th external conditions, $j = 1, 2, \ldots, n$; p_{ij} — the possibility of realization of the j-th external conditions when making the i-th desicion.

As shown in [2], the goal (reducing the possibility of large losses) can be achieved if the risk assessment of the i-th decision as a measure of the possibility of realization of certain losses $\boldsymbol{e}$ use a special replacement function $P_i(e)$, reflecting (as accurately as possible) the possibility of large losses [3-5].

Construction of compensatory functions in uncertain environment

A compensatory function must meet the following requirements [2].

First, the function $P_i(e)$ must belong to such a family of functions defined on the $\boldsymbol{e}$ axis $f(e, h)$ with the parameter h, at which one of the following conditions must be satisfied for all e from the interested to us area:

$$\text{if } h_a > h_b, \text{ then } f(e, h_a) \geq f(e, h_b);$$
$$\text{if } h_a > h_b, \text{ then } f(e, h_a) \leq f(e, h_b).$$

Second, the values of the compensatory function $P_i(e)$ and function f(e, h) should lie in the following interval

$$0 \leq f(e, h_b) \leq 1.$$

The first two requirements are obvious. When formulating the third requirement, we note that the compensatory function should reflect the possibility of large losses with increasing uncertainty in decision-making. Therefore, it is advisable to formulate the third requirement in the following form:

$$P_i\,(e) = f\,(e, h_i),$$

where h_i is the value of the parameter h at which the difference between the functions $f\,(e, h)$ and $P_i\,(e)$ is minimal for all the values of h in the H_i area where the condition is satisfied:

$$f\,(e, h) \geq P_i(e).$$

This means that the function f (e, h) provides the highest accuracy of the upper limits of the possibility of large losses with increasing uncertainty. To satisfy the last requirement, a special function was introduced in [2]:

$$q\,(p, B) = (1 - B \times \ln p)^{-1/B})$$

The value p here is the value of the compensatory function $P_i(e)$, i.e. in this case $p = P_i(e)$. B parameter determines the degree of uncertainty in the considered decision-making situation.

According to the condition (2), the value of p lies in the range $0 \leq p \leq 1$, therefore, the function q(p, B) is always non-negative and its values also lie in the interval [0,1]. It follows that for all the losses e from the range of values E,

$$\text{if } P_i(e) = P_j(e), \text{ then } q[P_i(e), B] = q[P_j(e), B]$$
$$\text{and if } P_i(e) > P_j(e), \text{ then } q[P_i(e), B] \geq q[P_j(e), B].$$

Therefore, when assessing the risk, the comparison of compensatory functions $P_i(e)$ can be reduced to a comparison of functions $q[P_i(e), B]$, which in this case can also be a measure of the possibility of the i-th event associated with losses **e** [6-9].

The value B can take any value in the interval [0, +□]. Moreover, the greater the value of B, the greater the degree of uncertainty in the decision.

Risk assessment in uncertain conditions

Now previous considerations allow us to move on to the quantitative assessment of risk. According to the definition introduced earlier, risk is the product of the amount of loss **e** received as a result of a decision, by the extent of the possibility of occurrence of the event associated with this decision, i.e.

$$r = e \times q(p, B). \quad (6)$$

Given that $p = P_i(e)$, and the compensatory function is subject to the above requirements, the amount of risk must belong to a certain set of R_i, which can be expressed [10-13] as follows:

$$R_i = \{r | r \in R^+ \cap \forall e \in E \ r \geq e \times q[P_i(e), B]\}. \quad (7)$$

To perform the inequality included in (7), it is necessary to consider the behavior of the compensatory function $P_i(e)$. When the value of losses in the interval $e_{ij-1} \leq e \leq e_{ij}$ $(j = 2, ..., n)$, the function retains a constant value, i.e. $P_i(e) = const$. When the value of losses reaches the set values, i.e. at $e = e_{ij}$ the function $P_i(e)$ decreases abruptly. Hence, the maxima of the function $r = e \times q[P_i(e), B]$ correspond to abscissae $e = e_{i1}, e_{i2}, \ldots, e_{in}$. It follows that the maximum risk value is determined by the formula

$$\max(r) = \max\{e \times q[P_i(e), B]\} = \max\{e_{ij} \times q[P_i(e), B]\}, \quad (8)$$

$$e \in E \ e \in E \ j \in N_i,$$

where $N_i = \{j \mid e_{ij} \in E\}$.

It is obvious that the inequality $r \geq e \times q[P_i(e), B]$ is equivalent to the inequality

$$r \geq \max\{e \times q[P_i(e), B]\}, \ e \in E$$

Then, given (8), the expression (7) will take the form

$$R_i = \{r | r \in R^+ \cap r \geq h_i\}, \quad (9)$$

where $h_i = \max\{e_{ij} \cdot q[P_i(e_{ij}), B]\}. \ j \in N_i$

In addition, in order to meet the requirements for the compensatory function, it is necessary that [2]:

$$f(e, h) = 1 \text{ at } e \leq h, \ (10)$$

$$f(e, h) = \exp(-1/B) \cdot \exp[-1/B(e/h)^B] \text{ at } e \geq h$$

This implies the correctness of the first condition (1), i.e. if $h_a > h_b$, then

$$f(e, h_b). \quad (11)$$

When assessing the risk of the i-th decision, it is necessary to choose the minimum value among the whole set of risk values $r \in R_i$. Then it follows from (9) and (11) that

$$r_i = \min r = h_i \quad (12)$$

Thus, taking into account (5), (9) from the expression (12) it follows that the value of the risk of the i-th decision is determined by the formula

$$r_i = \max\{e_{ij}[1 - B \cdot \ln P_i(e_{ij})]^{-1/B}\}. \quad (13)$$

$$r \in R_i$$

To determine the parameter *B*, a finite set *P* of so-called training objects should be given, the level of safety of operation of which is objectively known and can be estimated by a numerical indicator. This allows us to form a kind of approximating objectively existing reality (training) matrix of paired relationships between these objects [14]:

$$Q = \|q_{rk}\|_{p,p}$$

The size of the square symmetric matrix Q is determined by the number p of the considered training objects from the set P, and its elements q_{rk} are the known squares of distances between the r-th and the k-th training objects on the axis of preference from the safety point of view [15, 16].

To construct the relation S on pairs of training objects, we determine the square of the distance between the r-th and the k-th training objects on the z-axis by the formula:

$$s_{rk}(b) = (z_r - z_k)^2 = \left[\sum_{j=1}^{m} b_j\left(x_{rj} - x_{rj}\right)\right]^2.$$

Then the observed structure of relationships between training objects on the z-axis

$$S(b) = \|s_{rk}\|_{p,p}.$$

The vector b is fixed.

We will assess compliance with the functional.

$$B = \sum_{r=1}^{p-1}\sum_{k=r+1}^{p}\left[s_{rk}(b) - q_{rk}\right]^2.$$

The value of this functional shows the degree of uncertainty in the evaluation of the decision-making results.

The structure of relationships between training objects and the relationships observed on the z-axis of the structure are discussed above.

Conclusion. The assessment model of the degree of uncertainty in technical decision-making is constructed. It is based on a comparison of the training sample data with their assessment by the proposed indicators in the model.

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