CURRENT CONCEPT OF RISK: THE HIGHER THE PROBABILITY OF AN EVENT, THE LOWER THE RISK

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Abstract

With the adoption of a new concept of risk in the economy (ISO 31000:2009), the main task of risk assessment is to justify the adoption of management decisions under conditions of uncertainty. Within the framework of the new concept, a new fundamental definition of risk (risk - the effect of uncertainty on objectives) was established. The most important practical consequence of the new concept of risk was introduction of concept "likelihood" instead of "probability". Another paradoxical conclusion follows from the current definition of risk, which is important for understanding the essence of risk and improving risk assessment methodologies in current conditions is: the higher the probability of occurrence of the assessed event, the lower the "actual risk" associated with this event.

Keywords: risk, probability, likelihood, uncertainty, OHSI method

I. Causes and consequences of the risk management revolution

In 2009 (ISO 31000 standard) the revolution in understanding of risk and tasks of risk management, which actually began at the end of the XX century, was completed. However, this event, its causes and consequences have not yet been sufficiently noticed and studied by both the scientific community and practitioners.

To assess the value of risk, the past conception used the following definition: risk is a combination of the severity of possible harm and the probability of occurrence of this harm. This is a particular variant of the modern fundamental definition, which leaves open the question of what we mean by "harm" (whose harm, what is harmed) and what "probability" we mean (objective or subjective).

Let us call this approach technocratic, because it is focused on risk assessment in the area of presumably known initial data, is based on precise mathematical methods, and its central element is the very process of obtaining values of risk elements (probability and harm) without taking into account the possibility of its further use of results in the interests of risk management.

Since in the previous (before 2009) assessment of risk value was associated with the term "probability" (probabilistic risk assessment, PRA), the methods of classical probability theory, statistical methods were used for its assessment.

It is not difficult to see that if we use these methods to estimate probability, then:

- we assume a high degree of confidence in the initial data, which are based either on reliable statistics of the flow of homogeneous random events, or knowledge of the actual state of all elements of the system at any point in time;
- as a result of such an assessment, we do not receive a risk value for decision-making purposes, but a reasonable forecast of the state of the system for a given period, assuming that the input data included in the risk assessment remain unchanged;
- management decision-making in such a model is based not on uncertainty and risk assessment, but on predetermination and confidence in the preservation of the established trend.

At the same time, obviously, we cannot use the classical approach to assessing probability when assessing the risk of rare or unique events, where we must use the term "likelihood" and apply fundamentally different methods of assessing likelihood rather than probability.

The modern definition of risk (risk - the effects of uncertainty on objectives) puts in the center of the risk management problem namely the uncertainty of the future and implicitly introduces the main actor of risk management - the owner of risk (decision maker, LPR), who is both the owner of the goal and responsible for the failure to achieve the goal as a result of risk realization.

Risk assessment within the framework of the modern concept is based on the following assumptions:

- the situation in economy, politics, technology, social relations is changing so fast these days that any past statistics loses its meaning (there are no statistics);
- events of interest to the risk manager (decision maker) are so rare and differing in essential features (not homogeneous) that it is impossible to form a representative sample of them (there are no frequency);
- development of technologies (innovations) requires risk assessment in the absence of information about similar activities and similar events (there were no similar events at all).
- the purpose of risk assessment is to assess the magnitude of the impact of an unfavorable event on the purpose of the activity (comparison of the purpose of the activity, probable damage and costs for the implementation of preventive measures).

Despite the fact that the objective needs to change the concept of risk arose at the end of the XX century, in economics the new concept of risk was formalized only in 2009 with the release of the international standard ISO 31000).

Nevertheless, until now among modern scientists and practitioners dealing with the problems of risk assessment, the followers of the previous concept of risk, based on objective probability, certainly prevail [1, 2, 3]. It is interesting to note that the PRA approach is also used to assess the risks of such rare events as earthquakes [4] or events that have not yet occurred [5].

The promoters of the subjective-probabilistic approach, to whom the author includes himself, are still underrepresented both in scientific publications and in practical developments.

A detailed analysis of these two views is given, for example, in [6].

II. The higher the probability of an unfavorable event occurring, the lower the risk. Paradox or obviousness?

The term "probability" is usually understood as either a frequency probability, somehow related to statistics (representative sample) of past similar cases, or to a homogeneous flow of events, or to the availability of reliable objective information (facts) about the possible occurrence of this or that event. From which we can conclude that a rating of "probably" means a high degree of confidence that the event is " very likely" to occur in the foreseeable period of time. A high degree of certainty that an event is "very likely" to occur means a low level of uncertainty about the decision to respond to that event.

Estimates of the probability of low-probability events can be obtained with a high degree of confidence on the basis of large-scale sampling (thousands of homogeneous events) or accurate knowledge of the actual characteristics of a system or process (based on objective research or monitoring). This case is characteristic of statistical methods used, for example, in quality management systems (QMS) in mass homogeneous production.

However, in risk management such a situation seems to be fundamentally impossible. For rare or unique events occurring in the sphere of economy, politics, global cataclysms (earthquakes, tsunamis), the estimation of probability (more precisely - likelihood) of occurrence of such events can be obtained only with a very low degree of reliability. This excludes the possibility of their use for decision-making purposes.

On the contrary, a low level of uncertainty means low effects of uncertainty on objectives and therefore low risk in decision making, regardless of the magnitude of the probability! Therefore, risk as effects of uncertainty on objectives (i.e., within the 2009 concept) decreases simultaneously with the reduction of uncertainty both in terms of estimating the magnitude of harm and in terms of estimating the probability of an event occurring.

This article deals with "risk" within the framework of the modern concept of 2009 (ISO 31000), which in the limit allows for the complete absence of information about past events. The degree of probability of occurrence in the future of an extremely rare in the past or unique event is negligible, but the occurrence of the event is not excluded, which determines the high level of uncertainty and its effect on the decision on the need to take measures to respond to the risk. Therefore, instead of the term "probability" in the framework of the modern concept of risk, the term "likelihood" is used, which initially implies a low degree of confidence both in the initial data and in the results of probability and risk assessment.

As is known, when designing the protection of the Fukushima NPP, it was assumed, based on previous observations, that earthquakes with a magnitude of more than 8.5 were "practically" impossible. Nevertheless, the main shock occurred with a magnitude of 9.1, which caused a tsunami wave whose height in the area of the plant exceeded the calculated height by almost 10 meters. It should be noted that according to some studies, earthquakes with a magnitude of more than 9 in this area were accepted as "extremely unlikely".

This is the seeming paradox: at high values of event probability, risk assessment for decision-making purposes does not require special knowledge or techniques, since taking measures to reduce risk is obviously necessary if the damage is assessed as unacceptable. This conclusion is valid in the area of evaluating the possibility of the event occurrence, where we can speak exactly about "the probability", i.e. the event is more expected than impossible.

At the same time, the maximum risks of decision-making are associated precisely with rare or unique events, the probability of occurrence of which is negligible, but not excluded (likelihood), and damages (harm) are assessed as critical or catastrophic. These events are characterized by low probabilities and extremely high degree of uncertainty.

Therefore, the statement "the higher the probability, the lower the risk" is true only within the framework of the modern concept of risk (2009), where the definition "risk - the effects of uncertainty on objectives" is used, and the concept of likelihood is used instead of probability.

Thus, the use of "likelihood" instead of "probability" in the modern concept of risk is not just a formal replacement of the term, but a fundamentally important distinction, reflecting a change in the focus of attention in risk assessment from statistically expected events, the possible effects of which on objectives have already been taken into account, to low-probability events that have critical effects of uncertainty on objectives, and their consideration in management is characterized by high cost and uncertainty.

III. The essence of uncertainty in risk management

The key concept of the modern concept of risk is uncertainty. Physics and computer science use the concept of uncertainty, similar to the concept of entropy, which reflects the measure of uncertainty in the state of any system. To estimate the amount of uncertainty (information entropy) Shannon's formula is used [7]

$$H_e(x) = -\sum_{i=1}^{n} P_i \; log_2 \, P_i. \tag{1}$$

It follows from the Shannon formula that the uncertainty value H_e is related to the probability of an event nonlinearly, $H_e \to 0$ if $P \to 1$ and $P \to 0$ and has a maximum near the point $P \approx 0.37$ (Fig.1).

Although the uncertainties of the credible (P=1) and the impossible (P=0) events are equal in the limit, however, it is just as obvious that the information entropy function behaves differently in areas close to 0 and close to 1.

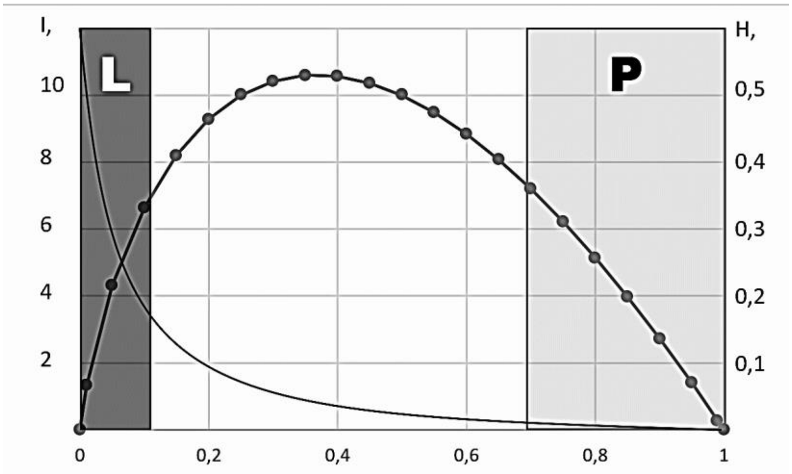

Figure 1: *Probability, likelihood and uncertainty*

The uncertainty of occurrence of extremely unlikely events (L, likelihood, q) is indeed substantially larger than that of their corresponding extremely likely (P, probability, P=1-q) events.

In general, formula (1) describes the uncertainty of the current state of the system, which is characterized by N possible states. That is, the entropy measure is the difference between the information contained in the new message and the part of information that is precisely known (or well predictable) in the message.

However, in the field of risk management, due to the lack (absence) of precisely known information, the general assessment of uncertainty (uncertainty) of the state of the system as a whole is not of practical importance. The decisive value is the assessment of certainty (certainty) of finding the system in a certain specific state from the set N or the possibility of transition of the system to such a state. Consequently, in the field of risk management it is necessary to consider uncertainty not in the form of information entropy, but in the form of self-information (2), which is a measure of uncertainty (unexpectedness) of occurrence of a certain event or being of the system in a certain state.

$$H_s\ (x) = -log_2\, P_x. \qquad (2)$$

That is why the ISO 31000 standard introduces the concept of uncertainty not in the form of information entropy, but in the form of self-information, i.e. complete or partial absence of information necessary to understand an unfavorable event, its consequences and their probabilities. In purposeful activity, the probability of a favorable outcome is much (by orders of magnitude) higher than a negative one, and its uncertainty is significantly lower. Therefore, in risk management, the probability of a negative outcome is usually considered, because a favorable outcome is expected (planned and ensured).

Passing in the uncertainty assessment from the information entropy formula to self-information, we will see even more significant difference in the values of uncertainties in the areas P and L (see the table below).

For example, if the values of uncertainty H at probability values $P_P = 10^{-1}$ and $P_L = 10^{-3}$ differ in times, then the values of uncertainties at the magnitude of the lack of self-information differ by four orders of magnitude.

Thus, a high probability of being a system in a critical (dangerous) state contains a low uncertainty and, accordingly, a low level of risk in making a management decision to prevent the dangerous situation: "unambiguously - to act!". Conversely, a low probability of the system being in a dangerous state contains a high level of uncertainty: whether to act (to bear, possibly, excessive costs) to prevent the development of the situation or to wait ("maybe this time it will not happen").

Table: *Significant difference in the values of uncertainties in the areas P and L*

Likelihood (L), q	Probability (P), P=1-q	H_L/H_P	I_L=-log₂ L, bit	I_P=-log₂ P, bit	I_L/I_P
0,001	0,999	6,91	9,97	0,001	9970,0
0,01	0,99	4,63	6,64	0,014	474,3
0,05	0,95	3,07	4,32	0,074	58,4
0,1	0,9	2,43	3,32	0,152	21,8

In the framework of the ISO 31000 concept, this leads us to a seemingly paradoxical conclusion: **the higher the probability of a hazardous event (in the P zone), the lower the associated uncertainty in decision making, i.e. the lower the risk of the risk owner.**

At the same time, in the L (likelihood) zone for rare and unique events this rule does not work anymore, because the use of the term “probability” is excluded. And for events with expected catastrophic consequences, not only the assessment of the probability of occurrence of the event on the basis of the classical probability or "frequency", but also the assessment of risk on the basis of the formula "risk - the product of the probability of occurrence of the event by the amount of harm" loses its meaning.

V. The problem of estimating the probability and risk of rare events

As noted earlier, in the presence of a steady stream of events in the past, risk assessment is effectively a prolongation of past losses on the basis of deriving probability from the past frequency of events for future periods (Fig. 2). Generally speaking, this goes beyond the scope of risk management tasks for several reasons discussed in section 1.

When assessing risks caused by rare or unique events, the main task is to estimate the likelihood of their occurrence in the future in the absence of information about their frequency or, in general, about their occurrence in the past, that is, in the absence of any information about the value of probability. This leads to the task of determining the likelihood of occurrence of some event in the future on the basis of information about the current state of the analyzed system.

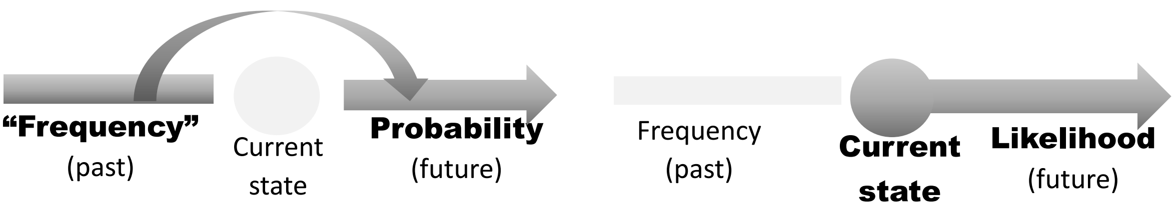

Figure 2: *The evolution of the concept of risk from statistical (on the left) to the concept based on uncertainty (on the right)*

On risk assessment in the L (likelihood) area, we usually do not have sufficient information about the probability of occurrence of events that are known to be rare, unique or assumed to be almost impossible.

In the traditional approach as a value of risk it is accepted to consider a combination of probability of occurrence of a dangerous event and severity of its consequences. In practice, as a combination is considered the product of

$$R = P \cdot W. \quad (3)$$

In the case of critical risks, this approach is not suitable, because the assessment of the probability of occurrence of an extremely unlikely hazardous event has no factual basis, and either does not give an idea of the actual value of the risk, or serves as a source of unfair manipulation. For example, if the estimated amount of harm is billions of dollars, then by simply manipulating the probability value (e.g., to 10^{-6}) the level of risk can be reduced to negligible (thousands of dollars).

In fact, estimates of extremely small probabilities (less than 10-3) are based, usually, on assumptions rather than on facts. Therefore, it is the economic (subjectivist) approach to probability estimation, outlined, for example, as early as in *de Finetti* [8] and developed in [9], that works in this range of probabilities.

De Finetti proposed to estimate the probability of occurrence of the event of interest related to economic consequences on the basis of game theory, weighing the possible benefits and losses from taking a particular decision regarding risk:

the probability of an event is the price *at which the person assigning the probability is neutral between buying and selling a ticket that is worth one unit of payment if the event occurs, and worthless if not.*

In relations to risk assessment, this statement should be understood in such a way that in the case of critical risks, it is advisable to consider a combination of the magnitude of the expected damage, the level of likelihood of causing such harm and the amount of costs for preventing the expected harm

$$(1-q) \cdot C \leftrightarrow q \cdot W,$$

from where it follows

$$q = \frac{C}{C+W} \approx \frac{C}{W} \ ,$$

where W is possible harm (cost); C is the allowable costs of avoiding harm ($C<<W$); q is the subjectively estimated probability of harm ($q<<1$).

That is, based on the de Finetti approach, the likelihood of a dangerous event in risk management is subjectively estimated as the ratio of the allowable costs of preventing harm to the magnitude of this harm. In the given example, it was assumed that protective measures are absolutely effective (E=1) and completely prevent (exclude) a dangerous event and the associated damage W. In fact, any preventive protective measures involve costs (this is, in fact, the essence of the risk problem), but have limited effectiveness E<1. In this case, the total losses W_Σ (the sum of the probable damage W and the cost of preventing it C) will be

$$W_\Sigma = q[EC+(1-E)(C+W)]+(1-q)C \approx C+qW(1-E).$$

If we exclude from consideration the subjective component of q (will happen or will not happen) and assume that the identified possibility of harm as a result of a possible adverse event is still realized (in an arbitrary period of time), then the formula of total losses (residual risk)

$$R_r \approx C+W_\Sigma(1-E),$$

and taking into account the assumptions C<<W, E→1

$$R_r \approx W(1-E),$$

where the expression in parentheses (1-E) represents the total estimated probability of an adverse event, provided protective measures are taken with the overall effectiveness of E.

Based on this approach, the author has developed a risk assessment method, which is called the OHSI Method (OHSI, Occupational Health & Safety Institute) [10], which is implemented in the Russian national standard GOST R 12.0.011-2017. This method was developed for the field of occupational safety, characterized precisely by rare heterogeneous events (frequency 10^{-2} ... 10^{-3} per year per 1000 employees) with significant damage (injuries and deaths of workers at work).

The method is based not on an analysis of the frequency of past allegedly similar events, which do not happen in the field of occupational safety, but on the use of objective information about the availability, protective properties (effectiveness) and the current state of protective measures. In the OHSI Method, the probability (likelihood) of the occurrence of an adverse event is assessed through the effectiveness of protective measures (barriers) that prevent the realization of the danger

$$P=1-E_{\Sigma},$$

where E_{Σ} is the total effectiveness of protective measures, defined in such a way that in the absence of protective measures the probability of occurrence of the event is equal to 1 (credible event), and when the source of danger is eliminated P=0 (impossible event). An example of calculation of E_{Σ} for several protective measures is also given in [10].

For practical application of the OHSI Method, a procedure (technology) has been developed, including two special ranking techniques for establishing the severity of consequences from identified hazards and establishing the effectiveness of protective measures. The registers formed in this way are the measuring tools of the OHSI Method. With the volume of registers more than 20 items, such registers provide quantitative nature of risk assessment and a high degree of objectivity of the risk assessment procedure, which is extremely necessary for the implementation of an effective risk management system of the organization.

The procedure based on the OHSI Method is automated and has been successfully applied in practice in the assessment of occupational injury risks, including as a methodological basis for OH&S management systems (OHSMS).

The disadvantage of the OHSI Method is only apparent when it is applied to critical events: extremely unlikely events (accidents) with catastrophic consequences. To significantly reduce the risk in these cases requires protective measures with a performance of 0.99...0.999, which cannot be confirmed on the basis of the ranking methodology. In this situation, the standard methodology for establishing the effectiveness of protective measures is not sufficiently convincing and requires uncertainty reduction.

As possible solutions to this problem, currently considered are:

- instrumental confirmation (monitoring) of preservation of design structural parameters of the object that affect safety (strength of the structure, condition of the foundation and soil);
- supplementing design structural solutions with special structural measures aimed at increasing the strength and stability of the structure under changed conditions;
- monitoring of availability, application and preservation of design parameters of special protective measures;
- application of statistical methods from the QMS field to identify trends in the change of protective properties (effectiveness of protective measures), etc.

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