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A NEW METHOD OF OCCUPATIONAL RISK ASSESSMENT, BASED ON UNCERTAINTY

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Abstract

This article aims to present a brand new method of quantitative risk assessment (OHSI method), in line with a modern concept of risk based on uncertainty. The OHSI method has been designed to determine the possibility of dangerous event occurrence through an assessment of the effectiveness of enabled risk controls. The IBT method has abandoned completely the use of the notion of "probability" in risk management context in favor of "likelihood", which enables a quantitative assessment of the magnitude of risk without involving historical data on event rate.

Keywords: Risk, risk assessment, probabilistic risk assessment, OHSI method, likelihood

I. Introduction

At the beginning of the 21st century, global economy actually adopted a new risk concept based on uncertainty. This turning point has been embodied in the international standard ISO 31000:2009. However, the underlying reason for the adoption of this standard was actual unsuitability for the purposes of risk management of the previous risk concept based on classical (frequency) probability in the new extremely volatile socio-economic situation. Regretfully, scientific community seems to have ignored this groundbreaking shift in the methodology of practical risk management has so far remained virtually unnoticed. Most scientific reports still dwell on outdated probabilistic statistical methods and approaches to risk assessment.

The tenet of the impossibility and inadmissibility of using the concept of "frequency (of past events)" in modern risk management becomes apparent simply by taking a closer look at the concept of the "event", which in modern risk management is interpreted as 'occurrence or change of a particular set of circumstances'. The world today is overwhelmed by multiple, breathtaking changes in technology, social and industrial relations, global (climatic, epidemiological) conditions to such great extent that our times' slogan boils down to the conclusion that "nothing happens twice". In other words, it can be argued that in actuality one can barely assume a likelihood of the occurrence of even two similar risk-relevant "events", to which the concept of "frequency" could be applied.

It follows from the above that the notion of "frequency" has become irrelevant with regard to risk management. However, given no "frequency", then there is no place in risk management for either probability in its classical sense, or probabilistic and statistical methods of risk assessment. Moreover, it will be shown later that in light of modern concept of risk, the following statement is true: "the *higher* the frequency of a dangerous event, the *lower* the risk caused by this event." The above statement, of course, is true only if the concepts of "risk", "event" and "frequency" are understood according to international management standards, which regulate real economy.

As we give up the use of the notions of "frequency" and "probability" in risk management and suggest their replacement with 'likelihood', the following standpoints shall be revised:

- "probabilistic risk assessment" (PRA) - the most common approach to risk assessment in the technosphere is, which is based both in name and in essence on an outdated concept of classical probability, which fails to convey modern and future events of real life economics [1, 2];
- the most common methods (techniques) of risk assessment (event tree analysis (ETA), value tree analysis(VTA), fault tree analysis(FTA), Failure mode and effects analysis(FMEA), human reliability analysis(HRA), common-cause-failure analysis (CCF), etc.).

This work does not contain an extensive references list, since the new concept of risk has not yet gained ground within the realm of economics. As a matter of fact, very few scientific papers tend to explain and support modern concept of risk because, naturally, academic economics lags behind real economy (economic science explains and turns into theory existing patterns of economic relations) and because of subjective factors associated with a need for alternative scientific approach. In addition, the need to publish scientific papers in peer-reviewed periodicals greatly impedes the promotion of "non-classical" scientific views that can affect the author's Hirsch index.

First of all, the transition to a new concept of risk requires an overhaul of scientific toolkit. Instead of probability theory and mathematical statistics, information theory, game theory, fuzzy set theory, and the Bayesian approach (subjective probability) have become the fundamental scientific basis of risk management.

Awareness of the discrepancy between the previous concept of risk, based on the classical probability and, accordingly, on the frequency of past conditionally homogeneous events, and the actual needs of practical risk management led the author to develop a new method of risk assessment, known as the Method of the Institute of Occupational Safety (OHSI method). The method is based on the modern idea of risk as the influence of uncertainty on goals (according to ISO 31000) and is embodied in the national standard GOST R 12.0.011-2017. This, in turn, automatically disables the use of the traditional concept of probability, and prompts to take a closer look at the concept of subjective probability, which in modern risk management practice is actually represented by the term 'likelihood'.

II. On the interconnection between the 'frequency' of a hazardous event and the 'risk'

According to modern management standards, 'event is occurrence or change of a particular set of circumstances'. It follows from this that the concept of "event frequency" can only refer to events that have completely identical sets of essential circumstances (objects, subjects, conditions, causes, consequences). If such events occur randomly and often enough (there is a representative sample), then we can really estimate the probability of the occurrence of another event through the relative frequency of occurrence *of the same* (!) event in the past. And the higher the frequency of occurrence of event in the past, the greater the probability of its occurrence in a certain future time span. Incidentally, if we do not consider a certain time span, but only consider the "future in general", then the probability of such event occurring in the future will be strictly equal to 1 (certainty of event is confirmed by its assumed regularity in the future).

However, from the point of view of information theory, the higher the objective (frequency) probability of an event, the less new information (uncertainty, risk) it contains. From scientific point of view, the inverse ratio of 'frequency' and 'risk' is confirmed by the following calculations.

The classical *probability* P in the general case is a consequence of the 'frequency' of homogeneous events (cf. 'event' above)

$$P = lim\frac{n}{N}, \text{при } n \leq N \text{ и } N \to \infty,$$

where 'n' is the number of events of interest to us, and 'N' is the total number of events (independent trials).

Claude Shannon [3] suggested that the increase in information is equal to the lost uncertainty. Despite this assumption being self-evident, it has not been applied yet to risk management. However, a logical conclusion follows from this assumption that the amount of information obtained during the implementation of each outcome is inversely related to the *probability* of this event

$$I = -log_2 P,$$

where 'I' *is the amount of information contained in the event that reduces the uncertainty* (the so-called 'negentropy'), bit.

In information theory, the uncertainty (information entropy) 'H' associated with the event 'A' is estimated by the classical formula propounded by Claude Shannon

$$H = -\sum_{i=1}^{N}\{p(A_i)log(p(A_i))\},$$

where 'p' (A_i) is the probability of an outcome 'A'$_i$, an event 'A' having 'N' possible outcomes.

From the above formula for calculating uncertainty, it follows that neither certainly expected events (p (Ai)=1), nor impossible events (p(Ai)=0) contain both uncertainty and information. The maximum uncertainty is achieved when all possible outcomes are equally likely to occur.

Hence, it follows that *random events that often occur* with a high frequency in the past, with no purposeful intervention in the flow of events, are just as often expected in the future. Therefore, they are practically void of uncertainty, hence are 'risk-free', in its modern sense. This is why, the most important prerequisite for the application of the modern concept of risk management is fundamental inadmissibility of risk assessment based on the frequency of past events, the laws of distribution of random variables, statistical hypotheses that have only one bottom line – misleading of decision makers.

When the new measures (risk controls) are applied it means a change in a certain set of circumstances and it means a new event. In the field of risk management, the assumption that "the higher the frequency of hazardous event, the lower the risk caused by this event" is proved by the fact that if a hazardous event occurs frequently (or at least repeats regularly) and no measures are taken to prevent it in the future, therefore:

- either this event does not affect the goals (does not pose an imminent hazard, nor contains an unacceptable risk);
- or this event does affect the goals, but there is no risk management in the organization and, hypothetically, management system in general.

If an effective risk management system is implemented and operates in an organization, then every hazardous event that is relevant for the purposes of the organization can occur exactly once. Subsequently, effective corrective measures shall be taken to eliminate the cause of the event, which has occurred. Consequently, *it is this particular event*, which will never happen again ("nothing happens twice").

Thus, in *effective* risk management systems, the concepts of "frequency" and "probability" in relation to risk assessment in modern conditions have become irrelevant.

III. The essence of the IBT method

Initially, the IBT method was developed to solve the problems of Occupational Health and Safety (OHS), therefore, we will consider its specifics in this particular context.

As far as the tasks of risk assessment in the field of occupational safety (occupational risk) are concerned, the leading role is assigned to the assessment of the risk of injury to employees as a result of exposure to hazardous factors of the production process (hazard).

Previous probabilistic and statistical concept employed generic approach to determine the risk of injury

$$R = P(F_v)W, \text{при} P(F_v) = const$$

where 'W' is the future eventual damage caused by the occurrence of a random event, and $P(F_v)$'a' is the classical probability of the occurrence of this event, found on the basis of the (allegedly) "known" distribution law $F_v$or directly from the frequency 'v' of (allegedly) "homogeneous" events.

How can classical approach to *risk assessment* ensure risk management, that is, to establish *functional dependence of residual risk on the impact* on the risk? It turns out that only by taking responsive measures that affect the severity of the consequences 'W', since it is impossible to influence the classical probability obtained from historical statistics without the use of a "time machine".

It is for this reason that the use of not classical (objective, not controlled) probability, but subjective (controlled) probability (likelihood) for risk management purposes [4] seems to be not only a reasonable solution, but also a non-alternative solution.

In case of occupational risk assessment, it is no easy to assess the severity of an accident 'W', but the range of severity values obtained by the method of expert assessments (other methods are even less instrumental) is usually within one magnitude order. However, subjectively assessed values of the likelihood of an accident may differ by several magnitude orders. Therefore, the task of the most balanced and reasonable assessment of accident likelihood 'P' is way more important and complex than the assessment of severity W.

The hallmark, scientific and practical novelty of the IBT Method is that it is based on a brand new view of the likelihood of the occurrence of hazardous event, which strictly follows from the modern definition of risk – *the likelihood of the occurrence of a dangerous event caused by an identified danger is determined through overall effectiveness of all protective measures taken to prevent the implementation of this event:*

$$P = 1 - E_{\Sigma}, \quad (1)$$

where 'P' is the likelihood of an event occurring, and E_{Σ} is the total effectiveness of all protective measures taken.

It is the essence of the IBT method.

The proposed approach:

- eliminates the need to use frequency and statistical data to assess likelihood and risk (risk assessment can also be conducted with no past events available);
- links in the form of functional dependency the likelihood of accident occurrence (P) on the effectiveness of measures taken to prevent it (given no protective measures, P =1);
- makes it possible to assess the effectiveness and efficiency of risk management measures taken in relation to unacceptable risks, since the preliminary risk assessment and residual risk assessment are enabled via the same methodology toolkit.

IV. Implementation of the IBT Method in the field of occupational safety

The IBT method can be illustrated by such graphical models as the "bow tie" model or the "Swiss cheese" model with the following features:

- in relation to occupational safety management under the "bow tie" model (ISO 31010), the analysis of the multiplicity of causes and consequences of an event is impractical (as it increases uncertainty). As a result, the "bow tie" model degenerates into a "string tie" (see the figure);
- in the "Swiss cheese" model, which was originally formally propounded by James T. Reason [5] as "slices of cheese", the influencing factors and elements of the process are not taken into account as risk controls (they are risk sources), but only specific organizational or technical measures (actually, "security barriers") with a pre-estimated effectiveness are taken into account.

V. Graphical model of the IBT Method

The figure shows a graphical model of the IBT Method based on the "bow tie" diagram, according to which the risk associated with the implementation of a dangerous event can be found (calculated) by the formula (1), in which the likelihood is found through the formula

$$P = 1 - E_{\Sigma} = (1 - E_1)(1 - E_2)(1 - E_3).$$

where E_1 ... E_3 are preventive (proactive) protective measures, and E_4 are response (reactive) protective measures.

As we can see, reactive measures are not excluded from the risk assessment, but are taken into account in the risk assessment as controls that affect the severity of the outcome

$$W_2 = W_1(1 - E_4).$$

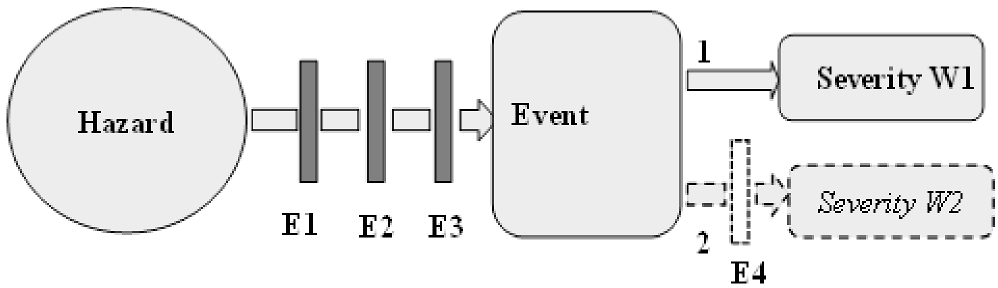
It is noteworthy that an event with a different outcome is already another "event" for which a separate risk assessment is required.

The objectivity of the IBT Method in conducting risk assessment is due to the following features of the procedure for applying the method, which provides for conducting risk assessment in three isolated stages:

- identification of all existing hazards and protective measures applied thereto;
- describing and ranking of hazards according to the severity of the consequences, while applied protective measures are described and ranked according to the degree of effectiveness;
- application of the register of hazards and the register of protective measures to risk assessment as unchangeable (objective) measuring tools.

Despite the simplicity of the mathematical apparatus, conducting a risk assessment using the IBT Method requires an extensive array of elementary calculations. Therefore, at present, a detailed risk assessment methodology has been developed based on the IBT Method, which is automated and practically used by many organizations in the form of a «Risk-Expert» software package, both for their own purposes and for providing risk assessment services.

The implementation of the IBT Method through the Risk-Expert software package has proved the expected advantages of the method for the purposes of assessing risks in the field of occupational safety in organizations aiming to achieve effective and efficient management of occupational risks.



The IBT method unlike qualitative subjective methods ("Matrix Method", "Fine-Kinney method" [6]):

- allows to obtain results of risk assessment that depend not on subjective opinion of an expert, but on identified hazards and objective workplace safety measures;
- provides a reassessment of residual risks (after taking risk management measures) using the same measurement tools (registers), which ensures the objectivity of the assessment;
- allows to evaluate generalized (total) risk levels of production processes, divisions for an objective comparison of the results of their activities, which cannot be achieved by subjective methods.

To date, the IBT method has proven its effectiveness in the field of occupational safety. However, the general principle of the method, i.e. the expression of the likelihood of an adverse event through a coordinated assessment of the effectiveness of security barriers, certainly deserves consideration for use in all High-Level Structure (HLS) management systems that implement risk-oriented thinking (QMS, EMS and others).

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