**Conclusions**. Implementation of modern designing technologies of mining processes based on concepts of databases in simulation, expert and geoinformation systems of ore mining and processing is a promising, yet not widely used potential for increasing mining efficiency.

The investigated control system connections and regularities allow formulating the principles of interconnections of a designed object, users and an exploitation object on the basis of analyzing and synthesizing the system controlling the design risks as well as developing control models system aimed at increasing mining efficiency.

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D.V. BROVKO, Cand. Sc. (Eng.), Assoc. Prof., Head of Research Department,
V.V. KHVOROST, Cand. Sc. (Eng.), Assoc. Prof., V. Yu. TYSHCHENKO, Research Assoc.,
Kryvyi Rih National University


## SAFE OPERATION OF SURFACE OBJECTS


**Purpose**. Development of a system analysis of current risks of possible structural design defects and organizational reasons for accident as one of the methods for assessing the reliability of structural elements in the mine surface objects that allows to control over operation safety.

**Methodology.** An analytical model for determining the risk assessment of a construction accident with collapse of structures has been developed. The technical condition of the mine surface object has been tested and the value of its actual survivability has been determined. To define the standard risk levels, the object is represented as a system consisting of connected groups of identical support elements. Modeling takes into account the key parameters including technical, human and organizational factors, as well as the cost for urgent safety work.

**Scientific novelty.** The scientific novelty of the method under consideration is an adequate description of reliability of surface mining objects structural elements, which takes its place among the up-to-date experimental studies of the industrial site safety**.**

**Practical significance.** The system analysis of the risks of possible design defects for determining the reliability of the object at some point in time and the safe residual resource has been developed. The proposed activities resulted in increasing cost and benefit assessment of implementing measures to reduce the risk of an accident based on the hazard identification. Final recommendations have been developed to manage the safe operation of the facility using the existing regulatory framework for labor protection.

**Results.** Three levels of risk are identified as follows: negligible risk, acceptable risk and unacceptable risk. The model that allows for systematic risk analyses of possible structural defects in construction by comparing its actual with acceptable boundaries has been obtained. The proposed methodology can be used to assess the survivability degree and the safe residual service life of an object.

**Keywords.** Risk, accident, reliability, safety, residual resource.

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The high level of injuries and especially accidents involving fatal injuries in Ukraine raises the issue of improving the prevention methods. In recent years, production in the world is estimated on the base of safety adverse event risk. The international organizations ISO, IMO and others have developed theoretical bases and methods of risk assessment and the technical solutions for the prevention from accidents and injuries in the workplace [1-3]. Experts from various industries in their reports constantly define not only "danger" but also such a term as "risk".

In the scientific literature there are various interpretations of the term "risk" and its definitions sometimes differ from each other by content. For example, the risk in the insurance terminology is used to refer to an insurance object (industrial enterprises or firms), an insured event (flood, fire, explosion, etc.), an insured sum (risk in monetary terms) or as a collective term to refer to unwanted or uncertain events. Economists and statisticians, faced these issues, understand the risk as a measure of the possible consequences, that will emerge at some point in the future. Psychological dictionary defines “risk” as an action aimed at attractive goal, the achievement of which involves elements of danger, risk of loss, failure, or as a situational characteristic of activity consisting in uncertainty of its outcome and possible adverse consequences in case of failure; or as a distress measure with nonsuccess in the activities, resulted by the combination of the probability and magnitude of adverse effects in this case. A number of interpretations reveal the risk as a probability of accident occurrence, danger, accident or disaster under certain conditions of production or human environment. These definitions emphasize the value of the vigorous activity of the subject and objective properties of the environment.

Common to the above distinctions is that the risk includes uncertainty, whether either an undesirable event occurs or an unfavorable condition arises. In line with modern views, risk is usually interpreted as a probabilistic measure of the occurrence of man-caused or natural phenomena accompanied by the emergence, formation and operation of hazards with ongoing social, economic, environmental and other harm and loss.

By the risk should be meant an expected frequency or a probability of hazard occurrence of a certain degree, or the amount of possible damages (loss, harm) against undesirable event, or some combination of these values. The use of the concept of risk, thus, allows to consider the risk as a measurable category. In fact, the risk is the measure of danger. The often use of the term "risk" (level of risk) essentially doesn't differ from the concept of risk, but only emphasizes that it is about the measurand.

All of these (or similar) interpretations for the term "risk" currently are used in the analysis of hazards and safety production management in general.

The risk occurs under the following necessary and sufficient conditions:

the existence of a risk factor (source of danger);

the presence of this risk factor in a dangerous (or harmful) dose for the impact object;

the exposure (sensitivity) of the impact objects to factor dangers.

Among accidents in different industries you can notice the obvious similarities. Usually an accident is preceded by the accumulation of defects in the equipment or deviations from the normal processes. This phase can last for minutes, days or even years. By themselves, the defects or deviations do not lead to an accident, but prepare the ground for it. The operators usually tend to overlook this phase due to the neglect to regulations or a lack of information about the work object, so that they do not have a sense of danger. The next phase is sudden or rare event that significantly changes the situation. The operators are trying to restore the normal process, but, not having full information, often only exacerbate the development of the accident. Finally, the last phase of another unexpected event - sometimes very little - plays the role of a push, after which the technical system ceases being governed by the people, and there is a disaster.

Risk is an inevitable concomitant factor of industrial activities. The risk is objective and characterized by suddenness, unexpectedness of onset. This involves the risk forecast, its analysis, assessment and control, i.e., a number of actions to prevent risk factors or lessening the impact of hazard.

Construction, reconstruction and operation of facilities on the surface of the mines belongs to the highest degrees of risk due to the specifics of work performance (lack of permanent jobs and increased risk of production processes), as well as organizational factors. This requires the improvement of the preventive measures in increasing construction safety through the existing risk assessment methods [4-9].

The aim of this work is to use a known technique for the analysis of potential accident hazards of facilities (structural collapse) and transform it to conditions of construction.

Human safety and environmental protection are the two interrelated problems of health and safety. International Standardization Organization (ISO) interprets safety as the absence of unacceptable risk with the possibility of damage [1].

On the basis of analysis and synthesis of the research results in the field of technogenic safety was developed a guide on Formal Safety Assessment (FSA) [2]. The FSA is a structured and systematic methodology designed to increase security, including the protection of life and human health, as well as environment and property based on a risk assessment taking into account the required costs and benefits.

Most often risk is defined as the frequency of realization of the unwanted event - a quantitative risk assessment [3].

The FSA considers the term "risk" as a product of damage caused by accident, that is, the risk value can be calculated from the following equation

$$R = \lambda \cdot Y\,, \tag{1}$$

where $R$ is the estimated risk value, 1/year or UAH./year.; $\lambda$ is the frequency of accidents of this type, 1/year; $Y$ is the damage caused by accident, without dimension or in UAH.

The dimension 1/year is used in estimating a risk of human death (individual risk) and the dimension of the UAH. /a year in assessing a risk of material loss or environmental risk.

In accordance with the FSA [2] the scale of risk has three areas. The first risk is negligible; the second risk is so great that it is considered excessive or inappropriate. Between these two areas is an area of acceptable risk, i.e. the risk, which is not so small to be ignored, but not large enough to consider it excessive.

In general, acceptable risk is the level of anthropogenic activities which society is willing to accept for the resulting economic and social benefits.

In accordance with the criteria adopted in the world practice [2], individual risk exceeding 1·10-4 1/UAH is considered unacceptable when during the year 1 death from 10000 is caused by undesirable events.

Acceptable is the individual risk, if its level lies in the range 1·10-4-1·10-6 1/year. This area of risk requires the special measures to its control. The risk value 1·10-6 1/year in well-developed countries is considered as the acceptable level of risk. An area of risk below this value suggests that the safety measures taken in technological activity are at a level that does not require special interventions for their improvement.

In assessing the degree of risk, the total damage caused by both the loss of life and material losses and environmental damage should be considered. It is necessary to consider the compliance of the material damage in monetary terms with the damage from the human death.

The used method is based on the concept of acceptable risk and identifies hazards before resulting to accidents. This takes into account technical, human and organizational factors, as well as the cost of improving security.

We performed a risk assessment of an accident constructions with structural collapse. Implementation of the methodology includes several stages.

The first stage is the assessment of the degree of accident risk and risk identification of its occurrence.

To estimate the risk value, we use the proposed method for determining the indices of frequency and damage caused by accidents with the use of a logarithmic scale, transforming it for conditions of our problem.

According to the methodology: risk = frequency *x* damage or

$$\lg R = \lg \lambda + \lg Y \tag{2}$$

then

$$R = 10^{[\lg \lambda + \lg Y]} = \lg \lambda \cdot \lg Y . \tag{3}$$

By introducing the notation $\lg \lambda = (FI - 6)$ and $\lg Y = (SI - 3)$ we obtain an equation for estimating the risk value

$$\lg Y = (SI - 3), \tag{4}$$

where *FI* is the frequency index of accidents; the number 6 is subtracted from the frequency index corresponds to the frequency value of 1.0 1/year (tab.1); *SI* is the index of damage caused by the accident (Severity Index); the number 3 subtracted from the index of damage corresponds to the relative damage of 1.0 (table.2); *RI* is the accident Risk Index, the values of which are given in table.3.

As you can see, the value of (-9) in the exponential expression (*RI-9*) of formula (4) corresponding to the frequency of accidents 1 per year, with the relative damage of 1.0 is taken as the base in determining the risk *R*. The risk value for other combinations of *FI* and *SI* is determined on the basis of statistical data or expert method using the table.1-3 [9-13]. In table.3, accident risk indices (*RI*) are the summation of the indices of damage (*SY*) and the frequency of accidents (*FS*). Having determined with the help of tables the risk index according to the formula (4), it is possible to set the numeric value of accident risk, to compare it with acceptable values and to make a conclusion about the level of considered risk.

Table 1

Accidents Frequency Indices

| FI | Accident frequency | Determination method | $\lambda$ (at one facility per year) |
|---|---|---|---|
| 1 | Extremely rarely | once in 100 years, at one of the 1000 facilities | 10-5 |
| 2 | | once in 10 years, at one of the 1000 facilities | 10-4 |
| 3 | Rarely | once a year, at one of the 1000 facilities | 10-3 |
| 4 | | once a year, at one of the 100 facilities | 10-2 |
| 5 | Moderately | once a year, at one of the 10 facilities | 10-1 |
| 6 | | once a year, at 1 facility | 1,0 |
| 7 | Frequently | once a month at one facility | 10 |

Table 2

Severity Indices

| SI | Damage from the accident | Influence on human | Influence on construction | Relative damage |
|---|---|---|---|---|
| 1 | Low | Individual or minor injuries | Local damage to the equipment | 10-2 |
| 2 | Significant | Numerous or serious injury | Insignificant damage to facilities | 10-1 |
| 3 | Severe | A single death or numerous injuries | Severe damage to facilities | 1,0 |
| 4 | Catastrophic | Numerous deaths | Complete destruction of facilities | 10 |

Table 3

Accident Risk Indices RI

| FI | Accident frequency | Severity (damage) caused by accident (SI) | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| | | low | significant | severe | catastrophic |
| 1 | Extremely rarely | 2 | 3 | 4 | 5 |
| 2 | | 3 | 4 | 5 | 6 |
| 3 | Rarely | 4 | 5 | 6 | 7 |
| 4 | | 5 | 6 | 7 | 8 |
| 5 | Moderately | 6 | 7 | 8 | 9 |
| 6 | | 7 | 8 | 9 | 10 |
| 7 | Frequently | 8 | 9 | 10 | 11 |

On the basis of statistical data, we assume that an accident with full collapse may occur once a year at one of the 100 structures, i.e., $FI$=4. This accident is usually accompanied by numerous deaths and causes severe structural damage, it refers to a severe $SI$=4. Then, on the basis of the data in the table.3 is determined the accident risk index $RI$=7.

Substituting the found value RI in the formula (4), we determine the risk value of an accident $R = 10^{[RI-9]} = 10^{[7-9]} = 10^{-2}$ 1/ year.

Comparing the obtained risk value with its permissible limits, we conclude that the risk of an accident facilities (structural collapse) is unacceptable (10-2 1/year > $R_{acceptable}$< 10-4 1/year) and requires for additional measures to reduce it [14, 15].

With this purpose, we identify the accident risk and evaluate the factors influencing the risk value by constructing a risk-sharing tree (tree of events and hazards).

The goal of the next phase is the selection of measures to reduce the accident risk based on the hazard identification.

The third stage involves the assessment of the costs and benefits of measures implementation proposed at the previous stage.

The final stage sets final recommendations on the construction safe operation management using the existing regulatory framework on labor protection.

**Conclusions.** Thus, a systematic analysis of the risk of possible structural defects and organizational reasons for accident occurrence enables to control safety in its operation.

We hope that after our more detailed studies, this technique could be applied in analyzing the risk of any process in the construction, repair and operation of buildings and structures on the surface of mining enterprise.

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