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IMPROVEMENT OF THE METHOD OF OPTIMIZATION OF INNOVATIVE RISKS AT MINING ENTERPRISES UNDER UNCERTAINTY

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УДОСКОНАЛЕННЯ МЕТОДУ ОПТИМІЗУВАННЯ ІННОВАЦІЙНИХ РИЗИКІВ ГІРНИЧОДОБУВНИХ ПІДПРИЄМСТВ В УМОВАХ НЕВИЗНАЧЕНОСТІ

Purpose. The aim of the article is the development of theoretical, methodological provisions and practical recommendations for the assessment of innovative risks of mining enterprises based on the theoretical and game modeling.

Methodology. The following methods were used in the research process: economic and mathematical modeling (for developing the method for optimization of innovative risks at mining enterprises under uncertainty on the principles of static theoretical and game); graphical (for visual presentation of research results); analytical, logical and structural (while optimizing the selection of innovative projects by the level of riskiness of investments).

Findings. A comprehensive approach to assessment of innovative risks at mining enterprises under uncertainty with using static theoretical and game modeling was proposed. A clear system of methodical positions suitable and convenient for use in practice has been developed.

Originality. The developed method for optimization of innovative risks at mining enterprises under uncertainty allows enterprises to make choices of innovative projects based on principle of optimality established by them, namely: little risk, minimal risk, moderate risk, minimal weighted average risk, maximum weighted average risk.

Practical value. The obtained results of research are aimed at solving the problem of optimization of innovative risks at mining enterprises. These results can be used in the process of formation of innovative strategy at the mining enterprise.

Keywords: *method, model, strategy, game theory, criteria, innovative risk*

Introduction. Without the development of innovative activity it is impossible to form and develop the market economy in Ukraine. Innovations in any industry including mining allow not only improving the production and increasing the competitiveness of manufactured products, but also creating additional jobs and, thus, they help to improve living standards both in a particular region and in the whole country. When carrying out innovative activity the main task for any mining enterprise is to search or develop those innovative projects whose implementation would bring it the maximum profit at minimum risks. However, to solve this task without modeling of risk situations in most cases is just impossible.

Analysis of the recent research and publications. Many scientists have been engaged in solving the problems for assessment of risk with the help of mathematical modeling, in particular, such as Manoilenko, O. V. [1], Matviichuk, A. V. [2], Palianytsia, V. A. [3], Sigal, A. V. [4] and others.

The feasibility of using the game theory in the optimization of risk was proved in the works of these authors. Criteria for making a decision are proposed to choose according to the informational situation, where the subject of management exists.

Unsolved aspects of the problem. The current concept of making decisions in the theoretic and game modeling is quite complex to apply in enterprises, since the best innovative project is difficult for the company to be determined as it has to follow its own established limitations.

Objectives of the article. The research of theoretical foundations and applied problems in the management of innovative activity of enterprises by modeling risk situations causes the formulation the following objectives:

- to develop a comprehensive approach to assessing innovative risks of enterprises under uncertainty by means of static theoretical and game modeling, which will allow enterprise to optimize innovative projects based on principle of optimality established by them;
- to develop a clear system of methodical positions suitable and convenient for use in practice.

Presentation of the main research. The need to use mathematical methods and models in assessing risks of innovative projects of mining enterprises has increased recently. This is due to the fact that enterprises want to be confident in their actions even in the face of uncertainty, which manifests itself in the presence of incomplete, inaccurate and contradictory information. Modeling of risk situations makes it possible to increase significantly the degree of validity of decision making on the optimization of options for innovative investments.

When carrying out innovative activities in a competitive environment with the probability of risk event occurrence in alternative innovative projects to be unknown, there are often conflict situations when the interests of different market participants collide. Game theory deals with making optimal decisions in conflict situations. In this case a conflict is believed to be the situation in which the opposing participants collide having different objectives, and everyone's winning will depend on the behavior of others.

There are three types of conflicts in the game theory: conflict of goals, which is characterized by different views of the parties of the conflict on expected performance in the future; conflict of cognition that is associated with incompatible views on solving the specific problem; sensitive conflict that consists in different feelings and emotions of the parties, as individuals [2].

Therefore, when constructing a mathematical model of modeling and evaluation of innovative risks for adequate display of features of a conflict, we should describe: the number of players (stakeholders), who may be individuals, enterprises, and various natural phenomena and the economy; possible strategies for each of the players, i. e. plans according to which a player makes a choice of their action with any possible information in any possible situation; a function of a prize or payment matrix that reflects the interests of the parties [5].

The essential difference between the game and the real conflict is that it is based on certain rules according to which possible moves of players are known, as well as about the amount of information of each party about the actions of the other one and the result which could be caused by the implementation of a certain sequence of moves.

The move in the game theory is understood as the selection and implementation of one of the possible actions that are allowed by the game rules. The combination of certain moves of the enterprise defines the strategy of a player. The main task of the game theory is to determine the optimal strategy i. e. such a strategy that would ensure the maximum possible winning for a particular player [1].

Since the subject of our research is static theoretical and game model, it is worth noting that sets of strategies during the game would be the same. Any game is set by a functional of assessment (a function of winning, payment matrix), which describes the "winning" or "losing" and would be as follows

$$A = \begin{array}{c|ccccc} & x_1 & \dots & x_j & \dots & x_m \\ \hline y_1 & a_{11} & \dots & a_{1j} & \dots & a_{1m} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ y_k & a_{k1} & \dots & a_{kj} & \dots & a_{km} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ y_n & a_{n1} & \dots & a_{nj} & \dots & a_{nm} \end{array},$$

where $Y = \{y_1, y_2, \dots, y_n\}$ are strategies of the first player (subject of management); $X = \{x_1, x_2, \dots, x_m\}$ are strategies of the second player (economic environment).

The functional of assessment will have as many rows as strategies that the first player has and, accordingly, as many columns as strategies that the second player has. The function of winning A can be both a positive (A^+), or negative (A^-), it depends on whether a maximum or minimum is being achieved. The functional of assessment will be negative in the case of optimization of risk or loss and positive when optimizing revenue or effectiveness.

Using the game theory one can solve many economic problems, including the question of calculating risk innovation projects.

Using the game theory you can solve many economic problems, including the question of calculating the level of risk innovation projects. However, currently existing paradigm regarding making decisions at theoretical and game modeling is quite complex to be used by the enterprise because it is quite difficult for the enterprise to determine the best innovative project, following the restriction formed by them.

Therefore, we proposed an approach that will enable the enterprise to choose the best innovative project for themselves, depending on their desired level of risk, which, unlike the existing ones, lets them put some optimality principles when interpreting the possible winning or losing as a result of the implementation of alternative innovative projects.

The mathematical model of risk assessment developed by us will be formed in several main stages at the theoretical and game modeling (Fig. 1).

The first stage. Determining the purpose for realization of innovative projects. As innovation can be in the form of investment in a new construction, manufacturing of innovative products, purchase of integral property complexes, new equipment, the expansion of the activity scope and its conversion, then making a decision on whether investing in specific innovative projects is rea-

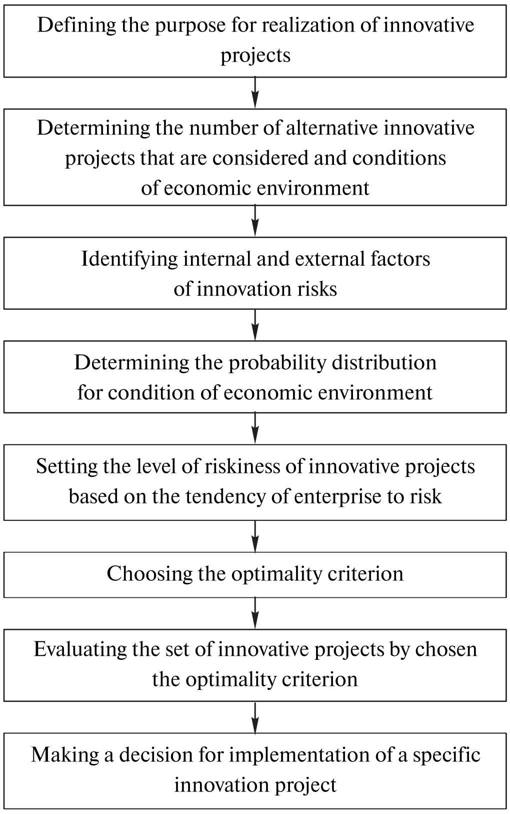

Fig. 1. The procedure for optimization of innovative risks at mining enterprises under uncertainty based on static theoretical and game modeling

sonable, the enterprise sets itself certain objectives. As a rule, there can be a lot of such objectives, but static theoretical and game model gives the possibility to optimize innovative projects according to one of them. Thus, the main task which an enterprise faces at this stage is to choose the most important one. As it is known one of the main objectives of innovative activity is to provide high return from the invested capital.

The second stage. Determining the number of alternative innovative projects that are considered and conditions of economic environment. The innovative projects of possible options for investing in operations with real assets are developed to achieve the goal at the first phase.

Payment matrix is constructed determining the number of alternative options. As the game theory stipulates that the functions of winning and a lot of strategies available to each player are known, so the subject for making decision can organize its behavior itself.

The third stage is the identification of internal and external factors of innovation risks. The results of innovation activities have significant impact on factors of innovation risks, which are generating uncertainty about the expected profit from the investment. Innovative risks exist independently from the will and desire of the enterprise.

They can be caused by both internal and external causes [6]. Internal reasons are primarily related to errors in planning and organization of innovation project.

The following factors can be considered as potential sources of internal risk: production capacity of the enterprise; the strategy of the development; the level of subject and technological specialization; the level of labor productivity; qualification of managers; professional unawareness of staff; indecency of managers; the low level of marketing; lack of flexibility of the project; flow of commercially sensitive information; technological indiscipline; lack of motivation of personnel; lack of financial planning; poor maintenance of equipment.

The external nature of risks conditions factors that are independent of a particular enterprise: growth of inflation; measures of state influence in the field of taxation, pricing, land use, financial and credit sphere, protection of the environment; international economic relations and trade; economic actions of contractors; competition; errors in determining demand; market conjuncture; political and economic crisis; reducing the overall living standards, growth of unemployment, strikes, changing needs, the criminal situation; the relative limitations of conscious human activity, the inevitable differences in social and psychological installation, ideals, intentions, estimates, stereotypes of behavior; NTP; force majeure circumstances.

The fourth stage. Determining the probability distribution of the economic environment.

When choosing an optimal strategy the subject of management does not have an antagonistic opponent, because the economic environment has no desire to win. The desire of each subject of management consists in determining the probability distribution of conditions of economic environment, as the probability is historically the first method of taking into account the uncertainty when making decisions. In determining the probability, the frequency of certain outcomes is investigated, which is not a characteristic of a single event, but is a general set of events. In this regard six information situations (I) are distinguished which characterize a certain degree of gradation of choice uncertainty of the environment about its states at the time of taking innovative decision [3].

The first information situation (I_1) is the most desirable for the subject of management, since a priori probability distribution is known in this situation $P = (p_1, \ldots, p_j.$, $p_j = p(x = x_j)$, $\sum_{j=1}^{n} p_j = 1$ on the elements $x_j \in X$.

The second information situation (I_2) is characterized by a known probability distribution $P(\eta) = (P_1(\eta), \ldots, P_n(\eta))$, $\sum_{j=1}^{n} P_j(\eta) = 1$, $P_j(\eta) = P\{x = x_j/\eta\}$ on the elements $x_j \in X$ environmental conditions. However, uncertain parameter η with the parametric set Ω has impact on this probability.

In the third information situation (I_3) the law of probability distribution of states of economic environment is unknown, so the subject of management itself sets the values of probability which we will designate p_j, $j = 1, \ldots, n$.

The fourth information situation (I_4) will take place when implementing innovations, since the probabilities of the behavior of the environment in this situation are completely unknown, they are determined according to certain hypotheses.

In the fifth information situation (I_5) the subject of management does not know the state of the economic environment, but it will try to reduce risk to zero. In other words, this situation is characterized by antagonistic interests of the environment in the process of innovative decision making.

The sixth information situation (I_6) is a situation that involves all five previous situations, on the one hand, to identify any information situation (I_1–I_5), and, on the other hand, there is information situation that is intermediate between the situations I_1–I_5.

The criteria for accepting an optimal solution in the game theory are divided into groups according to the information situation, that is, in each information situation a specific set of indicators is used [2].

The first information situation is characterized by the following criteria:

1. The Bayes criterion. When using this criterion, an enterprise will choose the innovative project y_{k_o} (or a plurality of projects), whose mathematical expectation of functional values of assessment will be the highest when A^+ or the lowest when A^-.

$$Z^+(y_{k_o}, p) = \max A^+(y_k, p) = \max MA^+ = \max\left[\sum_{j=1}^{n} p_j a_{k_j}^+\right],$$

or

$$Z^-(y_{k_o}, p) = \max A(y_k, p) = \max MA^- = \max\left[\sum_{j=1}^{n} p_j a_{k_j}^-\right].$$

2. The criterion of minimum dispersion of the functional of assessment. When using this criterion, the innovative project will be the one which will have the smallest dispersion of random variable of values of the functional of assessment.

$$\sigma^2(y_{k_o}, p) = \min \sigma^2(y_k, p).$$

3. The modal criterion in A^+ is calculated by the formula

$$y_{k_o} : a^+(y_{k_o}; Mo(X)) = \max a^+(y_k, Mo(X)),$$

where $Mo(X)$ is the mod of random variable X, which corresponds to the state of economic environment with the highest probability of occurrence.

With A^- optimal capital investment is calculated by the formula

$$y_{k_o} : a^-(y_{k_o}; Mo(X)) = \max a^-(y_k, Mo(X)).$$

4. The criterion of minimal semi-variation. The optimal solution for a given criterion does not depend on the form of a functional of assessment (A^+ or A^-) and is calculated by the formula

$$y_{k_o} : SV^-(y_{k_o}; P; \beta_{k_o}) = \min SV^-(y_k; P; \beta_k);$$

$$SV^-(y_k; P; \beta_k) = \frac{1}{P_k^-}\sum_{j=1}^{n} \beta_{k_j} p_j (a_{k_j}^{\pm} - Z^{\pm}(y_k; P))^2,$$

where $\beta_k = \{\beta_{k_1}; \beta_{k_2}; \ldots; \beta_{k_n}\}$ is the vector of indicators of unfavorable deviations for solution y_κ with respect to the Bayesian assessment $Z(y_\kappa; P)$ $(\kappa = 1, \ldots, m)$.

5. The criterion of minimum coefficient of variation for A^+ or A^- is calculated by the formula

$$y_{k_o} : CV^-(y_{k_o}; P) = \min CV^-(y_k; P),$$

where $CV^-(y_k; P) = \dfrac{\sigma^-(y_k; P)}{C^+(y_k; P)}$ is the value of the coefficient of variation for answer y_κ.

6. The criterion of minimal coefficient of semi-variation for A^+ or A^- is calculated by the formula

$$y_{k_o} : CSV^-(y_{k_o}; P) = \min CSV^-(y_k; P),$$

where $CSV^-(y_k; P) = \dfrac{SSV^-(y_k; P)}{Z^+(y_k; P)}$ is the value of the coefficient of semi-variation for the answer y_κ.

The following criteria are used in the second information situation:

1. The parametric Bayes criterion is calculated by the formula

$$\overline{Z}^+_\Omega(y_{k_0}, P) = \int_{\Omega_1} \ldots \int_{\Omega q} Z^+(y_{k_0}, P(\eta)) m_1(\eta_1) \ldots m_q(\eta_q) d\eta_1 \ldots d\eta_q =$$
$$= \max \int_{\Omega_1} \ldots \int_{\Omega q} Z^+(y_k, P(\eta)) m_1(\eta_1) \ldots m_q(\eta_q) d\eta_1 \ldots d\eta_q.$$

2. The parametric criterion of minimum dispersion for functional of assessment is calculated by the formula

$$\sigma^2(y_k, P(\eta) = \sum_{j=1}^{n} [a_{kj}^+ - Z^+(y_k, P(\eta))]^2 P_j(\eta).$$

3. The parametric modal criterion is calculated by the formula

$$\overline{P}_{j_1} = \max \int_{\Omega_1} \ldots \int_{\Omega q} P_j(\eta) m_1(\eta_1) \ldots m_q(\eta_q) d\eta_1 \ldots d\eta_q.$$

4. The parametric criterion of minimum entropy of mathematical expectation of functional of assessment is calculated by the formula

$$\overline{H}_\Omega(P, y_{k_0}) = \int_{\Omega_1} \ldots \int_{\Omega q} H(P(\eta), y_{k_0}) m_1(\eta_1) \ldots m_q(\eta_q) d\eta_1 \ldots d\eta_q =$$
$$= \max \int_{\Omega_1} \ldots \int_{\Omega q} H(P(\eta), y_k) m_1(\eta_1) \ldots m_q(\eta_q) d\eta_1 \ldots d\eta_q.$$

The third information situation is characterized by the following criteria:

1. The first Fishburne formula consists in building a number of priorities: $RI = [x_{i1}; x_{i2}; \ldots; [x_{ij}; x_{i\,j+1}]; \ldots; x_{in}]$, where x_{i1} is the state with the highest probability of occurrence; x_{in} is the state with the lowest probability of occurrence; $[x_{ij} \sim x_{i\,j+1}]$ are states with equal probabilities of occurrence.

2. Fishburne's second formula is used when there are partially strengthened linear correlations of order

$$P(X = x_{i_j}) = p_{i_j} \approx \hat{p}_{i_j} = \frac{2^{n-j}}{2^n - 1}, \quad j = 1, \ldots, n.$$

3. Fishburne's third formula is calculated by the formula

$$P(X = x_j) = p_j \approx \hat{p}_j = a_j + \frac{1 - \sum_{s=1}^{n} a_s}{\sum_{s=1}^{n} (b_s - a_s)} \cdot (b_j - a_j),$$

where p_j is given with interval correlations of livability $a_j \le p_j \le b_j$; $\alpha_j, b_j \ge 0$; $j = 1, \ldots, n$.

The following information criteria are used in the fourth situation:

1. The Bernoulli-Laplace criterion is calculated by the formula

$$Z^+(y_{k_0}, P) = \max a^+(y_k, P),$$

where $Z^+(y_k, P) = \frac{1}{n}\sum_{j=1}^{n} a^+_{k_j}$.

2. The Gibbs-Jaynes maximum entropy principle consists in finding Shannon entropy, which will represent the extent of uncertainty

$$\bar{H}(p) = \max H(p) = \max\left\{-\sum_{j=1}^{n} p_j, \ln p_j\right\}.$$

The fifth information situation in the economic literature is represented by the following criteria:

1. The Wald criterion. This criterion is also called the criterion of extreme pessimism, as innovative projects selected according to this criterion will be nearly risk-free. If the functional of assessment is set $A = A^+$, the Wald criterion will be based on the maxmin principle (Maximin) and calculated by the formula

$$y_{k_o} : \tilde{a}^+_{k_o} = \max \tilde{a}^+_k = \max \min a^+_{kj},$$

where $\tilde{a}^+_k = \min a^+_{kj}$.

For the functional of assessment given $A = A^-$ Wald criterion will be based on the minmax principle

$$y_{k_0} : \tilde{a}^-_k = \max \tilde{a}^-_k = \min \max_j a^-_k,$$

where $\tilde{a}^-_k = \max a^-_{k_j}$.

2. The criterion of dominant result is based on using (maxmax) strategy at $A = A^+$

$$y_{k_o} : \tilde{\tilde{a}}^+_{k_o} = \max \tilde{\tilde{a}}^+_k = \max \max a^+_{k_j}.$$

If $A = A^-$ the innovative project provided by the minmin strategy will be optimal

$$y_{k_o} : \tilde{\tilde{a}}^-_{k_o} = \min \tilde{\tilde{a}}^-_k = \min \min a^-_{k_j}.$$

3. The Savage criterion of minimal risk is only used when $A = A^-$ and is calculated by the formula

$$\tilde{a}^-_{k_i} = \min \tilde{a}^-_k = \min \max \tilde{a}^-_k.$$

4. Functions of uncertainty of the third kind are calculated by the formula

$$H(P) = \min Z^-(y_k, P) = Z^-(P),$$

where $Z^-(y_k P_j) = \sum_{j=1}^{n} P_j a^-_{k_j}$.

The choice of optimal innovative project in the sixth information situation occurs by such criteria:

1. The Hurwitz criterion when $A = A^+$ would be as follows

$$y_{k_o} : Q^+(y_{k_o}; \lambda) = \max Q^+(y_k; \lambda),$$

where

$$Q^+(y_k; \lambda) = (1 - \lambda)\max z^+_{k_j} + \lambda \min z^+_{k_j}; \quad \lambda \in [0;1].$$

If $A = A^-$, the optimal variant for investment will be determined by

$$y_{k_o} : Q^-(y_{k_o}; \lambda) = \min Q^-(y_k; \lambda),$$

where

$$Q^-(y_k; \lambda) = (1 - \lambda)\min a^-_{k_j} + \lambda \max a^-_{k_j}; \quad \lambda \in [0;1].$$

2. The Hodges-Lehmann criterion when $A = A^+$ is calculated using the formula

$$y_{k_o} : HL^+(y_{k_o}; P; \lambda) = \max HL^+(y_k; P; \lambda),$$

where

$$HL^+(y_k; P; \lambda) = (1 - \lambda) Z^+(y_k; P) + \lambda \min a^+_{k_j}.$$

If $A = A^-$, this criterion will be as follows

$$y_{k_o} : HL^-(y_{k_o}; P; \lambda) = \min HL^-(y_k; P; \lambda),$$

where

$$HL^-(y_k; P; \lambda) = (1 - \lambda) Z^-(y_k; P) + \lambda \max a^-_{k_j}.$$

3. The Menches criterion is determined by the formula

$$\sum_{i=1}^{l} \bar{P}_i \max a_{k_j} = \min \sum_{i=1}^{l} \bar{P}_i \max a_{k_j}.$$

The fifth stage. Establishment of the level of risk of innovative projects based on the tendency of enterprise to risk.

As a result of the research, we first proposed the classification of criteria for optimizing the selection of innovative projects in terms of investment risk, which allows implementing the choice not only depending on the informative situation, but by the following five groups of risk gradations as the maximum weighted average risk, weighted minimal risk, moderate risk, negligible risk, minimal risk (Fig. 2).

The proposed classification makes it possible to significantly simplify the process of adoption of innovative

Fig. 2. Classification of criteria for optimization of choice of innovative projects by the level of risk investments

solutions, since within the entire set of criteria that are characteristic for information situation, the ones are selected that give the optimal result from the perspective of the enterprise, i. e. its willingness to take risks.

Leveraging innovative solutions on the criteria of maximum weighted average risk the enterprise chooses the risk, the value of which will be slightly higher than the average level.

Selected innovative projects according to the criteria of this group will have the highest level of risk compared with innovative projects that would be selected by criteria for making decision of other four groups.

However, the enterprise inclined to risk does not only risk experiencing a bit more damage in case of failure, but can significantly reduce the risk of unused capacity in case of successful realization of innovative projects.

The average minimal risk corresponds to the average level of risk of innovative projects and therefore to the average level of risk of unused possibilities.

Moderate risk of unused possibilities is provided by criteria of decision-making that relate to the third group. When choosing an innovative project according to the risk of this level, the enterprise optimizes the ratio of the value of risk and expected return.

Insignificant and minimal risk orientates the enterprise on choosing those innovative projects which are less risky. However, an enterprise which is hardly prone to risks is in danger of undergoing maximum risk level of unused capacity and, therefore, of receiving less profit. However, the losses in case of failure of the enterprise will be minimal.

The sixth stage. Choice of the optimality criterion. The optimality criterion is chosen according to the proposed classification of criteria, optimization of choosing innovative projects by the level of investment risk (Fig. 2) and depending on the situation and established level of risk of innovation projects by the enterprise.

The seventh stage. Evaluation of the set of innovative projects choosing the optimality criterion.

Undoubtedly, the innovative project that will bring maximum benefit to the enterprise with minimal loss will be the best. However, if the enterprise has the desire to take risks, it may choose a riskier option, because the higher the risk is, the more profit it will receive in case of successful realization of the project.

At the final eighth stage the enterprise decides to implement a particular innovative project.

The innovative risk assessment with the use of the proposed method was carried out for four innovative projects of JSC "Kryvorizhzalizrudkom". The studied enterprise conducted the analysis of new markets regarding the production of new models of production line belts.

Possible models are A_1, A_2, A_3, A_4.

Unfortunately, the condition of the economic environment is unknown, i.e. the fifth information situation occurs.

According to the proposed algorithm of mathematical model for innovative risk assessment at theoretical and game modeling, we set the level of risk of innovative projects based on the tendency of enterprise to risk. Since the management of PJSC "Kryvorizhzalizrudkom" is not very inclined to take risks and it needs a guarantee that the potential level of loss is the lowest, then in this situation it is advisable to use the Wald criterion, which directs the enterprise toward the minimum risk i.e. toward extremely cautious line of conduct.

The matrix of possible losses that the enterprise may suffer in the process of implementation of each of the innovative projects in different states of economic environment P_1, P_2, P_3, P_4 was determined in an expert way and is given in Table.

According to the Wald criterion, an innovative project whose possible level of loss is minimal from all maximal in different states of economic environment will be the best(the principle "minmax").

The conditions of uncertainty and conflict, in which mining enterprises have to operate, have a significant impact on their future expected profits from the implementation of innovative decisions.

Since the process of innovative decision-making by the enterprise is understood as a choice of certain innovative projects from a plurality of alternative, then certainly this choice should be made according to certain optimality criterion.

As shown in Table maximum possible costs that which may be incurred by the analyzed enterprise, are:

Table

The matrix of possible losses of JSC "Kryvorizhzalizrudkom", thousands of UAH

	P_1	P_2	P_3	max
A_1	20	40	90	90
A_2	30	70	50	70
A_3	10	30	80	80
A_4	50	60	40	60

- 90 thousand of UAH on the first investment project;
- 70 thousand of UAH on the second investment project;
- 80 thousand of UAH on the third investment project;
- 60 thousand of UAH on the forth investment project.

As for the functional evaluation of given $A = A^-$ *the* Wald criterion is based on the principle of minmax, so JSC "Kryvorizhzalizrudkom" should choose forth innovative project, where the maximum possible losses that that the enterprise may incur are minimal.

Conclusions. The conditions of uncertainty and conflict, in which mining enterprises have to operate, have a significant impact on their future expected profits from the implementation of innovative decisions. Since the process of innovative decision-making by the enterprise is understood as a choice of certain innovative projects from a plurality of alternative, then certainly this choice should be made according to a certain optimality criterion.

In a theoretic and game concept the decision-making criteria are selected according to the information situation in which the subject of management is. However, when deciding on the choice of an innovative project it is not clear to the enterprise which to choose from the plurality of criteria.

The order proposed by us for optimization of innovative risks of enterprises under uncertainty based on static theoretical and game modeling enables the enterprise to choose innovative projects, optimizing them by five risk groups: negligible risk, minimal risk, moderate risk, average minimum risk, and average maximum risk.

Each of these risk groups enables the enterprise to optimize not only their losses in case of unsuccessful implementation of the project, but also returns.

Undoubtedly, the enterprise will receive the highest level of profits in case of making a decision on the criteria of maximum weighted average risk; however selected project will be the most risky in comparison with projects that would be selected by criteria of other four risk groups.

As it is known, the value of hoped profit reflects the magnitude of the risk i.e. only those enterprises receive excess profits that are prone to a higher level of risk. The author considers that it is necessary to investigate the practical possibility for applying static theoretical and game model in developing the innovative strategy of the enterprise for further study of the considered issue.

References.

1. Manoilenko, O.V. ed., 2015. *Research and optimization of economic processes*. Kharkiv: Kharkiv Polytechnic Institute.

2. Matviichuk, A.V., 2007. *Modeling of economic processes with the use of fuzzy logic methods*. Kyiv: KNEU.

3. Palianytsia, V.A., 2010. Conflicts and risks: applied aspect. *Social and economic problems and the state*, 1(3), pp. 94–99.

4. Sigal, A. V., 2014. *The Theory of Games for making decisions in the economy*. Simferopol: DIAYPI.
5. Shyian, A. A., 2009. *Theoretical and game analysis of rational human behavior and making decision in the management of social and economic systems*. Vinnitsa: Universum-Vinnytsia.
6. Syrotynska, N. M., 2013. The essence and factors for origin of innovation risks. *Scientific and theoretical journal, Khmelnitsky University of Economics "Science and economics"*, 1(29), pp. 96–100.

Мета. Розробка теоретичних, методологічних положень і практичних рекомендацій щодо оцінювання інноваційних ризиків гірничодобувних підприємств на засадах теоретико-ігрового моделювання.

Методика. У процесі дослідження використовувалися такі методи: економіко-математичного моделювання (для розроблення методу оптимізування інноваційних ризиків гірничодобувних підприємств в умовах невизначеності); графічний (для наочного представлення результатів дослідження); аналітичний і структурно-логічний (при оптимізації вибору інноваційних проектів за рівнем ризикованості капіталовкладень).

Результати. Запропоновано комплексний підхід до оцінки інноваційних ризиків гірничодобувних підприємств в умовах невизначеності з використанням статичного теоретико-ігрового моделювання. Розроблена чітка система методичних положень, придатних і зручних для використання на практиці.

Наукова новизна. Розроблений метод оптимізування інноваційних ризиків гірничодобувних підприємств в умовах невизначеності дає змогу підприємству здійснювати вибір інноваційних проектів за встановленими ним самим принципами оптимальності, а саме: незначний ризик, мінімальний ризик, помірний ризик, мінімальний середньозважений ризик, максимальний середньозважений ризик.

Практична значимість. Отримані результати дослідження направлені на вирішення проблеми оптимізування інноваційних ризиків гірничодобувних підприємств. Вони можуть бути використані у процесі формування інноваційної стратегії розвитку гірничодобувного підприємства.

Ключові слова: *метод, модель, стратегія, теорія ігор, критерій, інноваційний ризик*

Цель. Разработка теоретических, методологических положений и практических рекомендаций по оценке инновационных рисков горнодобывающих предприятий на основе теоретико-игрового моделирования.

Методика. В процессе исследования использовались следующие методы: экономико-математического моделирования (для разработки метода оптимизации инновационных рисков горнодобывающих предприятий в условиях неопределенности); графический (для наглядного представления результатов исследования); аналитический и структурно-логический (при оптимизации выбора инновационных проектов по уровню рискованности капиталовложений).

Результаты. Предложен комплексный подход к оценке инновационных рисков горнодобывающих предприятий в условиях неопределенности с использованием статического теоретико-игрового моделирования. Разработана четкая система методических положений, пригодных и удобных для использования на практике.

Научная новизна. Разработанный метод оптимизации инновационных рисков горнодобывающих предприятий в условиях неопределенности позволяет предприятию осуществлять выбор инновационных проектов по установленным им самим принципам оптимальности, а именно: незначительный риск, минимальный риск, умеренный риск, минимальный средневзвешенный риск, максимальный средневзвешенный риск.

Практическая значимость. Полученные результаты исследования направлены на решение проблемы оптимизации инновационных рисков горнодобывающих предприятий. Они могут быть использованы в процессе формирования инновационной стратегии развития горнодобывающего предприятия.

Ключевые слова: *метод, модель, стратегия, теория игр, критерий, инновационный риск*

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