

МЕНЕДЖМЕНТ ТА БІЗНЕС-АДМІНІСТРУВАННЯ

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FORECASTING AND MANAGEMENT OF INNOVATION AND INVESTMENT DEVELOPMENT OF IRON ORE ENTERPRISES BASED ON STOCHASTIC RISK MODELING

ABSTRACT

The article considers theoretical and methodological applied aspects of modeling and quantification of financial and economic risks in forecasting and managing innovation and investment development of industrial entities under conditions of uncertainty on the example of iron ore enterprises. It is established that the need to take into account stochasticity in forecasting and managing innovation and investment development of iron ore enterprises is due to random factors of the parameters of the development of iron ore deposits and increasing the impact of associated risks. At the same time, force majeure risks are important, in particular, due to the spread of coronavirus disease and others. It is concluded that the uncertainty in forecasting and managing the innovation and investment development of iron ore enterprises is reflected in the effective financial and economic performance of the enterprise.

The aim of the study is to develop applied theoretical approaches to risk management of iron ore enterprises to forecast the prospects of innovation and investment development, taking into account the impact of stochastic uncertainty inherent in the development of iron ore deposits and unforeseen associated risks.

In this case, taking into account stochasticity in forecasting methods requires modeling quantitative risk estimates based on the use of boundary theorems of the theory of probabilities of the law of large numbers.

As a result of the conducted researches the approach to economic and mathematical modeling of risk in forecasting and management of innovation and investment development of iron ore enterprises taking into account the set limit values of the interval of reliability of the forecast is developed.

Keywords: uncertainty; stochasticity; innovation and investment development; forecasting; risk.

Formulation of the issue

Today, industrial enterprises are the basis and basis of the country's economy and form the lion's share of national income. Modern domestic economic realities once again emphasize the

importance and significance of iron ore enterprises, which is a complex, single-product production system characterized by a large number of working people, machinery and machines, as well as a variety of relationships

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between them. However, in the production and economic activities of iron ore enterprises there is no physical phenomenon or process that would not be characterized in one way or another by factors of uncertainty and randomness. It follows that the course of processes in the system of production management of these enterprises is complicated by the gradual development of horizons for the development of iron ore deposits. In addition, the situation is exacerbated by the presence of certain aspects of the probabilistic nature of geological information on the geological and economic assessment of iron ore deposits. Here we can talk about the feasibility of using correlation-regression analysis of the dependence of specific natural resource consumption on such factors as: iron content in ore, the degree of averaging of ore, ore losses in technological redistributions.

One of the main conditions for the implementation of sufficiently reliable forecasts for the proper satisfaction of the needs of the market of iron ore products by the production of concentrates should be the introduction of the management of mining and processing plants (GZK) systematic innovative improvements. First of all, they concern the management of operating costs and yield of concentrate of a given quality from existing ore deposits. At the same time, the more factors are taken into account, the more detailed and in-depth the process is studied and the more accurate the scientific forecast becomes. Undoubtedly, the reliability of the results of monitoring the operational parameters of the available resources of iron ore (ZRS) plays an important role in this case. To a greater extent, this applies to the non-deterministic nature of blasting operations in the quarry, loading and transportation to the company's battery warehouses. Also not minutes and production and economic risks in the processing subsystem GZK "accumulating warehouse - concentrator" in the operation-oriented distribution of resources ZRS in the production of the required volume of commodity concentrates of a given quality. Under such conditions, strategic controlling becomes especially important as an integral part of the management of innovation and investment development of the enterprise. At the same time, a set of tasks is solved to monitor the risks of achieving quantitative and qualitative goals in

relation to the results of the implementation of its overall strategy. Important importance is attached to the analysis of economic efficiency, identifying the causes and consequences of deviations in the activities of the enterprise in order to eliminate them.

Analysis of recent research and publications

A large number of studies have been devoted to the need to analyze and assess the risks of a modern enterprise in terms of prospects for its innovation and investment development, which are reflected in many scientific papers. In particular, a number of studies substantiate the need to improve the organization of innovation development in conditions of constant risk, based on business modeling [2; 3; 4; 6] highlights the importance of addressing issues of innovation and investment activities from the standpoint of organizational and economic mechanism of economic activity and the level of investment market development and risk.

The purpose and objectives of the article

The aim of the study is to develop applied theoretical approaches to risk management of iron ore enterprises to forecast the prospects of innovation and investment development, taking into account the impact of stochastic uncertainty inherent in the development of iron ore deposits and unforeseen associated risks.

Presentation of the main material of the study

Manifestations of the impact of the main types of risk in managing the effectiveness of a modern manufacturing enterprise are reflected in the indicators of its financial performance, the prerequisite for the final assessment of which should be a qualitative risk analysis. In the first stages of the study, in the context of modeling GZK processes as a large single-product economic system, it is advisable to use more deterministic models. A classic example of a rigidly determined model is the optimization model for developing plans in a quarry system (which is a continuous system), which is used to determine the best options for economic development of a mining and processing enterprise among the many eligible.

This approach should be used in solving problems in which the result of the experiment depends on a small number of major factors that

remain constant from experiment to experiment. The solution of such problems is impossible when the result of the experiment depends not only on the main factors, but also on a large number of secondary random, which are interconnected and affect the result of the experiment. The influence of these secondary factors is so complex, and their number is so large that the replacement of a complex process (phenomenon) with a simplified model does not justify itself.

Thus, quantitative risk analysis in the management of modern mining is a rather difficult task because it involves determining the numerical parameters of individual risks of a large production system, taking into account the impact of associated risks of their operation.

In summary, it should be noted that in the quantitative assessment of investment risks the main attention is paid to the financial security of the enterprise, which is reflected in the values of financial indicators obtained on the basis of financial statements. Financial support is manifested in financial and economic relations that arise between the subjects of innovation and investment activities in order to obtain the greatest efficiency of economic results of the enterprise based on the use of organizational and managerial principles of innovation development methodology [8]. However, in this context, it should be noted that any form of innovation has the right to life, provided there is an appropriate level of its financial security, where an important role is given to the company's own funds.

The key issue regarding the final assessment of the level of raising funds for the development of innovation processes at the iron ore enterprise is the economic justification of the discount rate of future investment income. It is advisable to determine the size (level) of financial leverage, which is one of the most important indicators of the financial condition of the enterprise, which characterizes the ratio of debt and equity of the organization.

Therefore, the discount rate in the evaluation of innovation and investment measures should be determined on the basis of the ratio of attracted and equity, taking into account the above manifestation of stochastic features of mining development on the financial and economic indicators of the enterprise. To do this, enter into the calculations of the correction factor $k_p = 1 +$

W , where W – risk of stochastic features of mining and other related risks on the financial and economic indicators of the enterprise.

That is, it should be borne in mind that the vast majority of decision-making situations regarding innovative alternatives to industrial and commercial mining as a large iron ore enterprise are characterized by efficiency indicators that can be considered non-deterministic random variables. In risk theory, the two most appropriate for the conditions of GZK operation are widely used the main ways to determine the probability of occurrence of a random event: objective and subjective. In this case, the quantitative assessment of the degree of risk is carried out in both relative and absolute values, which reflect the degree of uncertainty inherent in the process of implementing the decision. Since the risk is caused by the uncertainty of decision-making situations for the implementation of production and economic activities of the entity, it is an urgent problem in choosing the strategy of risk management of the enterprise. In this case, the uncertainty factor may decrease as the information is clarified, but it is impossible to completely eliminate the uncertainty.

Financial managers, when solving the problem of determining the present value of money (PV) and their future value (FV) should pay special attention to the ratio of "money – time". The cost of capital FV_t after t years, taking into account the added interest payments should be calculated by the following formula:

$$FV_t = P(1 + (1+W) \cdot R)^t = P(1 + k_p \cdot R)^t, \quad (1)$$

where FV_t – future cost of capital in the t -th year; t – number of years; P – initial investment; W – risk of stochastic features of mining development on the financial and economic indicators of the enterprise; R – interest rate; $k_p = 1 + W$ – correction factor to the discount rate in the methods of evaluating innovation and investment measures.

Summarizing the considered characteristic features of the improvement of forecasting processes in the management of innovation and investment development of iron ore enterprises, risk assessment should be obtained using the methods of mathematical modeling. To quantify the risk of stochastic features of mining

development and other related risks on the financial and economic indicators of the enterprise (W) it is necessary to use risk measurement tools in both absolute and relative terms.

In absolute terms, the risk is nothing more than an estimate of the expected value of the projected result, if it can be measured. Sufficiently recognized estimates of the degree of risk should be considered mathematical expectation (mean), variance and standard deviation. In the system of variation indicators, the most practical is the variation scope indicator, which is the difference between the largest (X_{\max}) and the smallest (X_{\min}) value of variants. To measure the risk in relative terms, it is appropriate to use a coefficient of variation, which can be considered a criterion of a typical average. Sometimes, next to the coefficient of variation, as a relative indicator, you can calculate the oscillation coefficient, which characterizes the deviation of the extreme values of the indicator relative to its average value.

In the practice of quantifying the risk of GZK operation, it is often advisable to limit yourself to simplified approaches (based on one or more key indicators), which are the most important criteria in a particular situation. In particular, we can offer a fairly simple and proven method of determining the risk factor for short-term forecast: if the probability of reliability of the forecast is p , then the probability that it is not justified is $(1-p)$ [2]. At the same time, a simplistic but erroneous recommendation is often made, which is to rely solely on the mathematical expectation of an indeterminate measure of effectiveness in the face of uncertainty and the risk it poses. Of course, if you evaluate the effectiveness of a solution based only on mathematical expectation, there may be a situation where, in particular, two alternative solutions have the same value of the value of mathematical expectation. This approach does not exhaust the situation of uncertainty and does not allow to choose the best of the two alternatives or to avoid accepting either. However, it should be emphasized that the center of grouping indicators, which traditionally uses mathematical expectation, can be proposed in certain, specific situations (asymmetric probability distribution of random variables) to take mode or median [1]. In some cases, when estimating certain risk indicators, it is appropriate to use a

seven-square deviation in an unfavorable direction relative to the average values of the efficiency indicator.

As there are no quantitative indicators of sufficiently adequate assessment of the level of risk in relation to the existing risk situation, it is advisable to form a system of indicators for quantifying the level of risk, which can be used in the operation of GZK. The importance of this is explained by the fact that forecasting the qualitative and quantitative characteristics of iron ores and host rocks is carried out on the basis of exploration and exploration work, which fall under the probabilistic patterns of mass random events. This is reflected in the forecasting of the volume of iron ore and non-ore diversified products of short-term production (at least - potential), and hence the cost and other economic indicators.

To take into account the manifestation of stochastic features of the development of iron ore deposits on the financial and economic indicators of the enterprise, it is advisable to use in the risk modeling of boundary theorems of probability theory: Chebyshev, Markov, Bernoulli-Laplace, Poisson. In particular, the problem of taking into account stochasticity in forecasting and managing innovation and investment development of iron ore enterprises based on mathematical risk modeling can be rationally solved using Chebyshev inequality [2]:

$$P\{|X - M(X)| < \delta\} \geq 1 - \frac{\sigma_x^2}{\delta^2}, \quad (2)$$

where P – probability; X – random variable; M – mathematical expectation operator; δ – tolerance does not exceed a certain deviation X from $M(X)$; σ_x^2 – variance.

Applying Chebyshev's theorem, we obtain an enhanced inequality:

$$P\left\{\left|\sum_{i=1}^n X_i/n - \sum_{i=1}^n M(x_i)/n\right| < \delta\right\} \geq 1 - \frac{B}{n\delta^2}, \quad (3)$$

where B – a constant number that, by the theorem, does not exceed any of the variances; n – number of independent tests.

The partial case of the theorem shows [2]: if a random variable X was observed in n independent trials with mathematical expectation $M(X)$ and variance σ_x^2 , which can be considered as random

variables X_1, X_2, \dots, X_n with mathematical expectations $M(X_i) = M(X)$ and variances $\sigma_{x_i}^2 = \sigma_x^2$ ($i = \overline{1, n}$), then for these random variables the arithmetic mean is calculated by the formula: $\bar{X} = \sum_{i=1}^n X_i / n$. Based on the properties of mathematical expectation and the variance of random variables, we can show that $M(\bar{X}) = M(X)$ and $\sigma_{\bar{X}}^2 = \sum_{i=1}^n \sigma_{x_i}^2 / n$. Then you can write the inequality of the form:

$$P\{|\bar{X} - M(X)| < \delta\} \geq 1 - \frac{\sigma_{\bar{X}}^2}{\delta^2 n}, \quad (4)$$

where \bar{X} – arithmetic mean.

Particular attention should be paid to technical and economic indicators, which are characterized as random discrete quantities and have distribution laws that can not always be reduced to normal. Modeling and forecasting the quantitative values of such indicators should be carried out using the limit theorems of the theory of probabilities of the law of large numbers [1]. It is necessary to emphasize the positive aspect in the application of Chebyshev's inequality for forecasting technical and economic indicators of iron ore enterprises taking into account the risk. Namely, its properties allow us to investigate with sufficient reliability random variables with both normal and arbitrary distribution law, regardless of whether these values are positive or negative.

Based on inequality (4), using statistical information on the financial reporting of the

results of the enterprise in retrospect, you can build a model for forecasting a certain i -th financial and economic indicator with a given reliability of the forecast:

$$B^{+(-)} = M(X_i) \mp \frac{\sigma_x}{\sqrt{(1-p_{jnp})n}} = M(X_i) \mp \delta_{jnp}, \quad (5)$$

where $B^{+(-)}$ – quantitative value of the projected indicator; p_{jnp} – reliability of the forecast.

Formula (5) makes it possible to predict risk levels in absolute terms with a given reliability p_{jnp} .

The value of the level of risk in relative terms, taking into account (5) for a given interval of reliability of the forecast $p_{jnp_{jmax}jmin}$ [1]

calculated by the formula:

$$W = \left(\frac{1}{(p_{jmax} - p_{jmin})} \left| -\frac{2\sigma_x}{\sqrt{n}} (\sqrt{1-p_{jmax}} - \sqrt{1-p_{jmin}}) \right| \right) / \left(\frac{1}{(p_{jmax} - p_{jmin})} \left| -\frac{2\sigma_x}{\sqrt{n}} (\sqrt{1-p_{jmax}} - \sqrt{1-p_{jmin}}) \right| + M(X_i) \right), \quad (6)$$

where W – quantitative assessment of the level of risk in relative terms; p_{jmin} – lower limit of the forecast reliability interval; p_{jmax} – the upper limit of the forecast reliability interval.

Consider the example of using the proposed methodological approach in determining the discount rate for forecasting the future cost of capital in assessing innovation and investment measures based on financial statements of PJSC "Central GZK" [7] are given in table. 1.

Table 1. Financial and economic indicators of economic activity of PJSC "Central GZK"

Indexes	Years of the retrospective period						
	2014	2015	2016	2017	2018	2019	2020
Sales volume, UAH million	6272,2	6531,7	7102,2	10727,6	11338,8	12083,3	12438,8
Net profit, UAH million	770,8	688,0	2218,2	2707,9	2254,2	1473,3	1601,1
Equity, UAH million	5543,3	6265,4	5958,4	7071,5	7977,4	7242,5	7268,2
Cost, UAH million	5304,1	4157,4	3197,4	5690,2	6802,9	7958,0	8348,9
Long-term liabilities and collateral, UAH million	409,7	409,7	757,1	851,1	850,1	1255,7	2035,1
Current liabilities and collateral, UAH million	620,3	751,3	5895,3	6289,8	6817,2	9106,5	8694,9
Financial leverage, part of a unit	0,19	0,19	1,12	1,01	0,96	1,43	1,48

Taking into account the results of modeling risk assessments based on forecasts of financial leverage values when calculating the discount rate

for the implementation of innovation and investment measures according to formulas (5) - (6) are given in table. 2 and in fig. 1.

Table 2. The results of calculating the discount rate for the implementation of innovation and investment measures, taking into account the modeling of stochastic uncertainty in the development of mining operations

Values of probabilities of the interval of reliability of the forecast								Оцінка рівня ризику	
p_{jnp}	0,75	0,775	0,8	0,825	0,85	0,875	0,9		
Predicted values of financial leverage at a given reliability interval								W , part of a unit	W , %
B^+	1,31	1,33	1,36	1,39	1,43	1,48	1,54	0,0751	7,51
Calculation of the discount rate taking into account the correction factor $k_p = 1+W$								R^* , part of a unit	R^* , %
$R^* = (1+W) \cdot R$, at a given interest rate $R = 0,15$: $(1+0,0751) \cdot 0,15$								0,1613	16,13

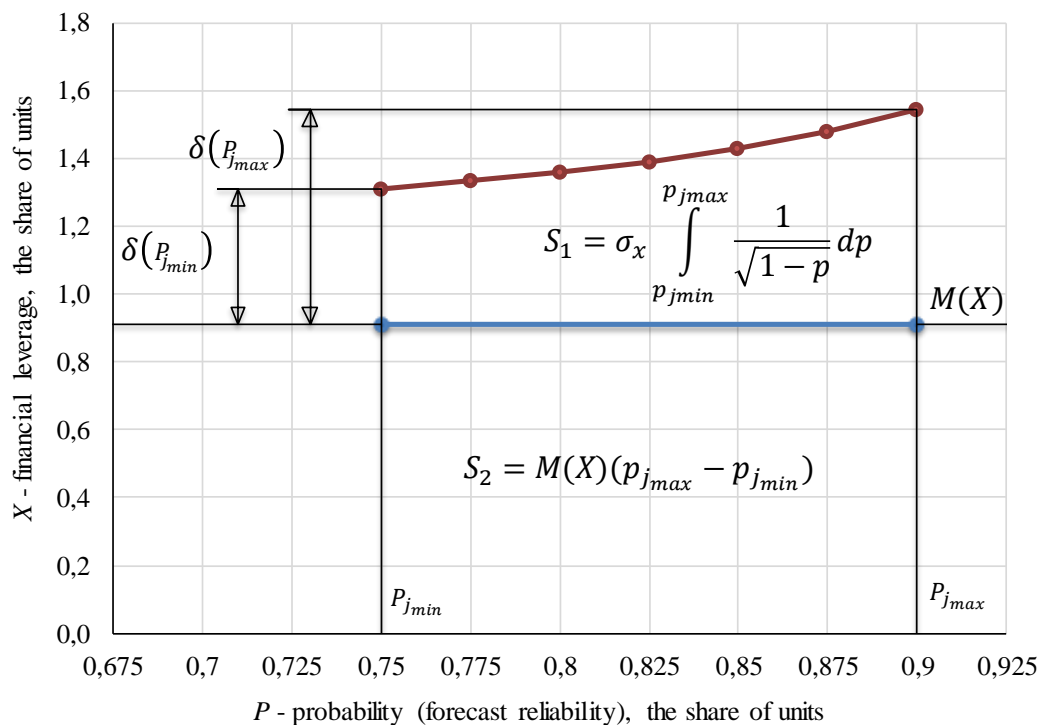


Fig. 1. Graphical interpretation of risk assessment in relative terms ($\delta(P_{jmin})$, $\delta(P_{jmax})$ – the value of possible deviations of financial leverage from its average value at the boundary points (p_{jmin} , p_{jmax}) forecast reliability interval ($p_{jnp_{jmaxjmin}}$))

Fig. 1 gives a graphical interpretation of the calculation of risk assessment in relative terms for a given reliability interval across areas S_1 and S_2 : $W = S_1 / (S_1 + S_2)$.

The results of calculating the discount rate taking into account the correction factor k_p , show that the value of the pre-predicted value of the interest rate ($R = 0,15$) increase by 7,51% (by the level of risk $W = 7,51\%$ (Table 2)). In this case, it should be borne in mind that the value of assessing the magnitude of the level of risk W directly depends on the choice of financial

managers of the enterprise the value of the interval of reliability of the forecast $p_{jnp_{jmaxjmin}}$, which is to some extent due to the risk appetite of financial managers.

Conclusions and prospects for further research

It is established that in contrast to rigidly determined models of optimization of GZK management processes, it is necessary to raise the issue of using a developed methodology for modeling financial and economic processes, which takes into account stochastics and uncertainty. In

forecasting and managing the innovation and investment development of GZK, the modeling of financial and economic risks and their assessment should be carried out taking into account the stochastic nature of the parameters of iron ore development processes and the impact of associated risks. A separate important issue is the consideration of force majeure risks when calculating the discount rate for the implementation of innovation and investment measures.

It is necessary to form data sets for modeling

situations of making innovation and investment decisions under conditions of risk, taking into account possible deviations from the average calculated values of the forecasted performance indicators at the set limits of forecast reliability.

The approach to taking into account the manifestation of the risk caused by the stochastics of iron ore management processes on financial and economic indicators can be used to control the movement of investment flows when forecasting the results of innovation and investment measures.

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ПРОГНОЗУВАННЯ ТА УПРАВЛІННЯ ІННОВАЦІЙНО-ІНВЕСТИЦІЙНИМ РОЗВИТКОМ ЗАЛІЗОРУДНИХ ПІДПРИЄМСТВ НА ОСНОВІ СТОХАСТИЧНОГО МОДЕЛЮВАННЯ РИЗИКІВ

Анотація

У статті розглянуто теоретико-методологічні прикладні аспекти моделювання та кількісної оцінки фінансово-економічних ризиків при прогнозуванні та управлінні інноваційно-інвестиційним розвитком суб'єктів промисловості в умовах невизначеності на прикладі залізрудних підприємств. Встановлено, що необхідність врахування стохастичності при прогнозуванні та управлінні інноваційно-інвестиційним розвитком залізрудних підприємств зумовлена випадковими факторами параметрів розробки залізрудних родовищ та підвищенням впливу супутніх ризиків. Водночас важливими є форс-мажорні ризики, зокрема, через поширення коронавірусної хвороби та ін. Зроблено висновок, що невизначеність у прогнозуванні та управлінні інноваційно-інвестиційним розвитком залізрудних підприємств відображається на ефективній фінансово-економічній діяльності підприємства.

Метою дослідження є розробка прикладних теоретичних підходів до управління ризиками залізрудних підприємств для прогнозування перспектив інноваційно-інвестиційного розвитку з урахуванням впливу стохастичної невизначеності, властивої розробці залізрудних родовищ, та непередбачуваних супутніх ризиків.

При цьому врахування стохастичності в методах прогнозування потребує моделювання кількісних оцінок ризику на основі використання граничних теорем теорії ймовірностей закону великих чисел.

У результаті проведених досліджень розроблено підхід до економіко-математичного моделювання ризику в прогнозуванні та управлінні інноваційно-інвестиційним розвитком залізорудних підприємств з урахуванням заданих граничних значень інтервалу достовірності прогнозу.

Ключові слова: невизначеність; стохастичність; інноваційно-інвестиційний розвиток; прогнозування; ризик.

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