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## **ANALYSIS OF THE POSSIBILITY OF USING MODERN RISK ASSESSMENT METHODS IN MINING INDUSTRY**

**Summary.** The article describes the components of the risk assessment process, the analysis and classification of modern approaches to the evaluation of risk events. Justification of the possibility of using the methods of statistical, analytical, expert assessment approaches is based on the division of the methods into the groups by types of risks assessed: technical, investment, bankruptcy, market, credit, operational, in-house risk, the risk of financial assets and portfolios. The application examples of the assessment methods in terms of mining industry were provided.

**Keywords:** risk identification and analysis, risk assessment, risk assessment methods, types of risk, terms of use of risk assessment methods.

## **ANALIZA MOŻLIWOŚCI ZASTOSOWANIA NOWOCZESNYCH METOD OCENY RYZYKA W BRANŻY GÓRNICZEJ**

**Streszczenie.** W artykule przedstawiono elementy procesu oceny ryzyka wraz z analizą i klasyfikacją nowoczesnych podejść do ewaluacji ryzyka w przedsiębiorstwie. Szczególną uwagę zwrócono na możliwość zastosowania metod statystycznych, analitycznych i eksperckich w ocenie ryzyka: technicznego, inwestycyjnego, bankructwa, rynkowego, kredytowego, operacyjnego, wewnętrznego oraz ryzyka związanego z aktywami finansowymi i tworzeniem portfela tych aktywów. W części empirycznej artykułu w postaci studium przypadków zaprezentowano przykłady zastosowania metod oceny ryzyka w branży górniczej.

**Słowa kluczowe:** identyfikacja i analiza ryzyka, metody oceny ryzyka, rodzaje ryzyka, warunki zastosowania metod oceny ryzyka, ocena ryzyka w górnictwie węgla kamiennego.

## 1. Introduction

The drive to the correct risk assessment is one of the fundamental ideas of modern economics. The application of various modern risk assessment methods provides an opportunity to reduce the number of errors, limits irrational activities through optimal selection and competent management decisions.

In the modern conditions of the mineral resource complex the attention is more often paid to the process of risk analysis and management, due to the deteriorating mineral resource base, market volatility and political factors, changes in the economic and legal regulators.

Many scientific works are devoted to the analysis of risk assessment methodologies, as well as present the estimation algorithms in the All-Union State Standards and international standards.

The purpose of this paper is to analyze the modern methods of risk assessment in order to identify the potential opportunities of their use in the mining industry, investigating the experience of the various methods for assessing the mining and geological, industrial, financial risks.

## 2. Analysis of the risk assessment methodology

Risk evaluation - the process of combining the identification, analysis and comparative assessment of risk<sup>1</sup>.

Risk can be assessed for the entire organization, its divisions, individual projects, activities or specific hazardous event. Hence in different situations the various methods of risk assessment may be employed.

Risk identification is the process of determining the elements of risk, making their list and compiling a description of each risk elements.

The aim of risk identification is a listing of risk sources and events that may affect the achievement of each of the stated organization's objectives or make it impossible to meet these goals. The process of risk identification involves determining the causes and sources of

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<sup>1</sup> Enterprise Risk Management - Integrated Framework Executive Summary.-Committee of Sponsoring Organization of the Treadway Commission (COSO), 2004; Risk management organizations. Integrated model. Rundown. COSO 2004, p. 10-11 [ electronic resource]. Mode of access: <http://www.bankir.ru>  
Guidelines for use of AS / NZS 4360 (Australian Handbook, HB 254-2003) AS / NZS 4360:2004 - Risk Management, issued by Standards Australia <http://www.sherq.org>  
ISO / IEC 31010-2011 Risk management. Methods of risk assessment [electronic resource]. <http://www.files.stroyinf.ru>

Demchuk I.N., N.V. Fadeykina: Innovations in the system of national standards in the field of management and risk management / Economics, No. 6, 2012, p. 76-84.

hazardous events, situations, risk circumstances that may have a significant impact on the achievement of organizational goals.

All the information about the characteristics of individual risks can be obtained from various sources: one-time and permanent, formal and informal. At the same time, the information used in the risk assessment process should be reliable, useful, timely and affordable to obtain<sup>2</sup>.

It should not be confused with cheapness or information availability, as the first characteristic is the data presence associated with the researched data sources, and the second one is related to the amount of resources (e.g., financial, due to the fact that the particular risk assessment techniques require a greater number of data sources than others) that are required to obtain the relevant data.

The usefulness of information means that for the identification or decision-making it is necessary to use an optimal set of valid data as obtaining redundant information provides additional costs. The reliability of information is the degree of the source confidence. The set of data is characterized by a low degree of confidence, it must have less influence on the decision making process or be completely excluded.

The examples of internal sources of information are: the production process data, marketing research, accounting statements, audit and audit materials, personal experience of the supervisor, a catalog of risk factors. The examples of external sources are: statistical data, predictive information, economic, political, demographic situation, information about the competitors, partners, suppliers and consumers.

Risk classification is based on the identification. The types of risks differ on multiple grounds - by the course of emergence, by the consequences, by the methods of reducing, or by the risk sources, by the risk bearing objects, by the subjects which perceive risk, by the specifics of individual industries and activities, by business processes, according to the stages of life cycle, and so on<sup>3</sup>.

The stage of risk analysis is a study of risk information. The risk analysis, that includes the determination of the probability and consequences of the identified hazardous events, provides the input data of the risk assessment process, helps in making decisions regarding the need for risk processing, and also helps to choose the appropriate strategies and methods of risk management. Data on the probability of events and their consequences are used to determine the level of risk.

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<sup>2</sup> ISO / IEC 31010: 2009 Risk management - Risk assessment techniques (IDT).

<sup>3</sup> Mineral resources of Russia. Economics and Management, No. 4, 2002, p. 36-41. Rogov M.A.: Risk management/ M.: Finance and statistika//2001, 120p. Mazur I.I., Shapiro V.D.: Investment and construction engineering/M.: Elim// 2014, p. 1216.

Atapina N.V.: Comparative analysis of risk assessment methods and approaches to risk management/Young scientists. No. 5, 2013, p. 235-243.

The methods used in the analysis of risk, may be qualitative, quantitative or mixed, Table 1<sup>4</sup>.

This classification corresponds to the subjects of "risk assessment techniques", but the standard does not provide the specific criteria for decision making and guidance on the application of risk analysis techniques in the specific situations, besides, the standard is intended for the companies in various industries. Other classifications of assessment methods offer derivatives of quantitative and qualitative evaluation.

The methods may be divided into groups by types and kinds - evaluation methods of technical, investment, bankruptcy, market, credit and operational risk, assessment methods of intra-risk, methods of risk assessment for the financial assets and portfolios<sup>5</sup>. In the vast majority of works devoted to risk assessment and risk analysis, as independent groups the statistical (mathematical-statistical, probabilistic), expert (heuristic) and analytical (computational and analytical) sometimes - analog methods are considered, Table 2.

Already within each group of methods (universal approaches to the study of the risks applicable regardless of their objective content, the specifics of the economic sphere and the situation) specific methods and techniques should be allocated that are adapted for different economic conditions and activities. And some of these techniques may be of narrow specialized nature, and some - claim to a greater or lesser generality, versatility, approaching thus the methods of analysis.

Table 1

## Categories of appraisals

| Group practices        | Qualitative risk assessment   | Quantitative risk assessment   |
|------------------------|---|--|
| Methods of observation | <ul style="list-style-type: none"> <li>• Checklists;</li> <li>• Preliminary analysis of hazards</li> </ul>  | -  |
| Additional methods     | <ul style="list-style-type: none"> <li>• Structured interviews and brainstorming;</li> <li>• The Delphi technique;</li> <li>• Method of structured scenario analysis of "what if?" (SWIFT)</li> </ul> | <ul style="list-style-type: none"> <li>• Human Reliability Analysis (HRA)</li> </ul> |

<sup>4</sup> ISO/IEC 31010: 2009 Risk management - Risk assessment techniques (IDT)

<sup>5</sup> Panyagina A.E.: Overview of modern methods of quantitative risk assessment // Economics and Management of innovative technologies. No. 3, 2014 [electronic resource]. URL: <http://ekonomika.snauka.ru/2014/03/3966> (request data: 10/10/2014).

Marinina O.A.: Methodological approaches to risk management standardization process/ Proceedings of International scientific and economics Conference named after academician P.P. Maslov, No. 2. Berlin: Wissenschaftlich Welt e.V., 2014, p. 89, p. 58-65.

continuation of table 1

|                     |   |  |
|---------------------|---|--|
| Scenario analysis   | <ul style="list-style-type: none"> <li>• Root cause analysis;</li> <li>• Scenario analysis;</li> <li>• Analysis of the impact on the business;</li> <li>• Cause-and-effect analysis</li> </ul>                                | <ul style="list-style-type: none"> <li>• Toxicological risk assessment;</li> <li>• Fault tree analysis;</li> <li>• Analysis of the event tree;</li> <li>• Analysis of the causes and consequences</li> </ul>   |
| Functional analysis | <ul style="list-style-type: none"> <li>• Analysis of hidden defects (analysis of parasitic chains);</li> <li>• Hazard and Operability Study (HAZOP)</li> <li>• Hazard Analysis and Critical Control Points (HACCP)</li> </ul> | <ul style="list-style-type: none"> <li>• Failure Mode and Effects Analysis (FMEA) and Failure Mode, Effects and Criticality Analysis (FMECA);</li> <li>• Maintenance, aimed at ensuring the reliability;</li> <li>• The Layer of Protection Analysis (LOPA);</li> <li>• Analysis of the "bow-tie"</li> </ul> |
| Statistical methods | -   | <ul style="list-style-type: none"> <li>• The Markov analysis;</li> <li>• Simulation method;</li> <li>• Monte Carlo;</li> <li>• Bayesian analysis;</li> </ul>   |

Source: ISO / IEC 31010: 2009 Risk management - Risk assessment techniques (IDT).

The method may provide better results when it matches the application evaluation, then the more complex procedure which is performed incorrectly. Usually the efforts on risk assessment should match the level of risk being analyzed; It should follow the recommendations of GOST, regarding the applicability assessment methods in the specific stages of the process: identification, risk analysis, comparative evaluation.

For example, the methods of "brainstorming", "structured interview", "Delphi technique", "check sheet", "Preliminary Hazard Analysis PHA" are useful for the identification of risk, but not acceptable on the stage of analysis and comparative assessment; the methods of "decision tree analysis", "Root cause analysis", "Analysis of the bow tie" on the contrary are not used to identify risks, but are strictly applicable to all stages of risk analysis (analysis of the consequences, the probability characteristics, the level of risk) and comparative risk assessment.

Comparative risk assessment uses the information about the risk, obtained in risk analysis. The results of the comparative risk assessment are used for making decisions for future actions.

When choosing a method it is necessary to take into account the uniqueness of each company, expressed through a set of indicators that describe the operations of the enterprise best and, at the same time, constitute a kind of entirety, which gives a comprehensive picture of the estimated object.

The concepts of risk assessment have their specific practical and theoretical significance. The possibility of application of the considered approaches for risk assessment of the company depends on conformity of the methods of determining risk exposure to the objective conditions, the properties of the economic environment, the availability of source data, the level of uncertainty, the complexity of the risky situation. The results of statistical, analytical and expert risk assessments are the basis for making decisions concerning risk management.

Table 2

## Categories of appraisals

| Methods  | Conditions of the method applicability  | Methods and models   | Advantages and disadvantages of the methods and techniques   |
|--|---|--|--|
| <p><b>Mathematical and statistical methods</b> - based on a study of the gains and losses statistics, that occurred in similar situations, and on the frequency and probability determination of the certain risk events occurrence.</p> | <p>Assessment of the portfolio, credit and operational risk, financial assets</p> | <ul style="list-style-type: none"> <li>• Capital Asset Pricing Model (CAPM), risk identification of the investments in financial assets CML (Capital Market Line), SML (Security Market Line);</li> <li>• The potential loss estimation: VaR, Short Fall, Capital-at-Risk, Maximum Loss, Stress or Sensitivity Testing.;</li> <li>• Design procedures: mean-square deviation, standard deviation, covariance, Monte Carlo method, the method of historical simulation.;</li> <li>• Methods: Risk Metrics, Credit Metrics, Credit Metrics+, Merton model, KVM-model.;</li> <li>• Assessment of operational risk for the bank: Basic Indicator Approach;</li> <li>• Risk coverage ratio of R. Cook.;</li> <li>• Risk matrix for decision used functionally: Wald, R. Savage, A. Hurwitz, V. Pareto, P.-S. Laplace;</li> <li>• Game theory methods of John Von Neumann and Morgenstern.;</li> </ul> | <p>They are objective, the most accurate. Based on the most deeply developed scientific and practical tools. Used both alone and in combination with the methods of other groups.</p> <p>They require an extensive database of reliable data for application, there is a possibility of standardizing certain business situations.</p> |

continuation of table 2

|  |   |   |   |
|--|---|---|---|
| <p><b>Expert methods -</b><br/>based on the use of knowledge and experience of highly qualified specialists in this subject area.<br/>ImPLY gathering, study and generalization of expert assessments.</p> | <p>Credit risk assessment:</p> <p>Bankruptcy risk assessment:</p> <p>Country risk assessment:</p> | <p>Scoring models, credit ratings, the methodology used by the Group of Companies "Interleasing" to assess the risk of leasing transactions</p> <p>Argenti's 'A' Score</p> <p>The ratings, models and indexes of international agencies: Moody's, Standard and Poor's, Fitch Ratings, Euromoney, Economist Intelligence Unit, Deutsche Bank, Institutional Investor (II) and others.</p>  | <p>Applied in all fields and areas to assess the risks of any type and kind, in the circumstances where there are no statistical data, mathematical models the task is difficult to formalize;</p> <p>Subjective, do not always provide reliable results for the risk assessment of a certain type and kind, often requires the development of special methods;</p> |
| <p>The Delphi technique, methods of "meetings", "court", "brainstorming", PATTERN analogies method (tree of objectives) method of synectics.</p>   | <p>Project risk assessment:</p>   | <p>The Technique of stagewise risk assessment of investment projects for the proposed investment and finance groups and the Russian financial corporation; sensitivity analysis (stress-testing); scenario analysis; decision tree; Monte Carlo method; risk-free method for constructing the equivalent of cash flow; method of risk-adjusted discount rate; critical path method (CPM); Program Evaluation and Review Technique (PERT) and Graphical Evaluation and Review Technique (GERT)</p> |   |

continuation of table 2

|   |  |   |  |
|---|--|---|--|
| <p><b>Computational and analytical techniques</b> - focused on studying of economic indicators, which are based on the functional relations or their probabilistic modeling parameters, determined with a greater or lesser degree of accuracy;</p> | <p>Risk assessment of technical objects:</p> | <p>Event tree, fault tree method "events - consequences." The techniques of the theory of mass service A.N. Kolmogorov, J. Little, A.A. Markov, S.D. Poisson, A.Y. Khinchin, A.K.Erlang.</p> <p>Z-score: Altman's Z Score, R. Taffler, J. Fox. Fulmer, G. Springeyt, Zh.Lego, J. Conan and M. Golder; R-models GV Davydova and AY Belikov, RS Saifulina and GG Kadykova; bankruptcy prediction coefficient W. Beaver, Chesser, AD Sheremeta, models YD Vishnjakova, OP Zaitsev and AI Savina;</p> <p>Methodology of evaluation the sufficiency of the balance sheet structure, developed FUDN</p> <p>Risk analysis in absolute and relative indexes: the grouping of assets and liabilities of the organization according to the degree of liquidity and payments promptness, diagnosis of the financial situation on the balance model, three-component index, type of balance sheet liquidity, analysis of the coefficients of financial stability and liquidity of assets, leverage analysis. Risk coefficient, an index of market efficiency of business operations. Break-even analysis, marginal analysis. Decision tree, the tree of events.</p> | <p>Applicable in many fields and areas of activity. Allow quantifying the risks and provide acceptable accuracy of its results. Easily combined with statistical and expert methods.</p> <p>Some methods can be used only in a situation close to full certainty. In some techniques approximation is necessary, there is subjective assessment of possibility that reduces its accuracy. Not all methods are universal.</p> |
| <p>Assessment of corporate risks:</p>   |  |   |  |

Source: Panyagina A.E. Overview of modern methods of quantitative risk assessment // Economics and Management of innovative technologies. 2014. No. 3 [electronic resource]. URL: <http://ekonomika.snauka.ru/2014/03/3966> (request data: 10/10/2014).

Marinina O.A., Tochilo M.V. The assessment of the marketing risks of JSC "Belaruskai"/ Proceedings of the International scientific-practical conference "Actual problems of science and education", Moscow: "AR-consult, 2014, Part IV, p. 34-37, ISBN 978-5-906353-97-9

### 3. Examples of using the submitted methods in the mining industry

In the sector of mineral resources companies, for the purpose of identification, analysis and assessment there are many tools of these valuating groups used. Operational risk assessment of mining industry includes an analysis of complex technological systems projects and technical solutions based on FMECA, HAZOP, "Analysis of latent defects" techniques that explore the types and consequences of technical systems failures, the danger of process parameters deviation (temperature, compression, etc.). from regulatory regimes. With the use of these methods it becomes possible to identify and rank the risks, evaluate inaccuracies in the safety instructions and improve them.

Practice shows that major accidents are usually characterized by a combination of random events occurring at different rates, at different stages of emergence and development of the accident (equipment failure, human mistake, overburden pressure, smoke jet, dust, explosion, etc.). To identify the causal relationships between these events the logical-graphical methods and "fault tree" analysis are used thanks to which it is possible to explore a combination of events that lead to accidents in mines<sup>6</sup>. Operational risk assessment is used for the engineering design and mine development stages in order to provide and optimize the security measures; for a comprehensive assessment of dangerous and harmful factors of mining operations; property insurance, etc.

The evaluation of geological hazards in mining science is based on the methods of mathematical statistics and applied since the 1899. The concept of geological risk in the study area corresponds to "error analogy" naming unit. Under the present conditions, the methodology for assessing the accuracy of inventory counting is the most developed and used in laboratory rocks studies, topographic, geophysical, surveying works, feasibility study projects, on the stages of planning and mining development of mineral deposits<sup>7</sup>.

To assess the investment and commercial risks we apply the adjustment methods of discount rate, the sensitivity analysis of performance indicators, scenario methods, decision tree construction. These techniques are used at the stages of project feasibility studies, at the preparation of business plans for the development and modernization.

In corporate risk assessment of mining companies the standard techniques of financial analysis can be used that are performed on computational and analytical method and implemented on the basis of availability of internal sources of information: the production process data, market research, financial statements, audits and audit materials, risks catalogs, personal experience of manager.

<sup>6</sup> Malashkin V.A., Pogorelaya Y.: Comparison of methods for assessing risk analysis at the mining enterprises. M.: Moscow State Mining University, GIABA, 2012, pp. 267-279.

ISO / IEC 31010: 2009 Risk management - Risk assessment techniques (IDT)

<sup>7</sup> Mineral resources of Russia. Economics and Management, No. 4, 2002, pp. 36-41. Boyarko G.Y. Strategic industry risks of mining industry. Thesis for scientific degree of Dr. sc. oec. Tomsk: Tomsk Polytechnic University, 2002, p. 370.

For operational risk assessment the methods of loss statistics analysis (VaR), identifying key performance indicators (KPI) can be applied, which characterize the risks concentration, adverse events in the business processes and in the structural units of mineral companies.

From the analysis of modern methodological approaches for risk assessment it stems that each of them has its practical significance and is aimed at solving the certain types of tasks based on the availability of source data, the level of uncertainty, the objective conditions. The purpose of the evaluation process is to identify a list of risk sources and events that may affect the achievement of the targets of mining companies, determination the risk level and comparison with the risk criteria. The choice of evaluation method affects depends on the accuracy and reliability of the results used in making decisions about the need for risk treatment and definition of strategies and risk management activities.

#### 4. Summary

The article discusses the theoretical and methodological aspects of risk assessment, including in the conditions of the mining industry. This study offers an analysis of modern risk assessment methods, potential possibilities identification of their usage in the mining industry, the application experience of research on various methods for estimating of mining and geological, industrial, financial risks.

The analysis of methods reveals the peculiarity of applying the statistical, expert calculation and analytical estimates.

It should be noted that despite the fact that the statistical approach is based on different scientific tools, it is not popular enough in real economy sector and difficult to adapt because of the complexity for the directing the officials or the company's analysts to understand the calculation mechanism, the accuracy of the results does not always guarantee appropriate decisions, most indicators are lagging calculations as it is a reflection of past trends.

The advantages are that the expert method can be used when there are no statistical data, mathematical model or there is a complexity in the formulation of the problem, but the results of such assessment depend on the subjective views of experts, their methodology type selection, parameters of estimation. The method is used more as an addition to the main assessment tools.

Calculating analytical method is widely used in mining companies, in a view of the results accuracy and its clear interpretation of quantitative estimates, there is a possibility of combining it with the expert and statistical, mathematical methods.

However, a lack of the methods universality should be noted as well as an assumption of approximation and subjective probability evaluation in the particular techniques.

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## Omówienie

Z analizy nowoczesnych podejść metodologicznych do zarządzania ryzykiem wynika, że każde z nich ma swoje znaczenie w praktyce i jest ukierunkowane na rozwiązywanie konkretnych typów zadań, w zależności od dostępności danych źródłowych, poziomu niepewności i innych, obiektywnych uwarunkowań. Celem procesu oceny ryzyka jest identyfikacja jego źródeł i ryzykownych zdarzeń, które mogą oddziaływać na wyniki przedsiębiorstw górniczych, jak również określenie poziomu ryzyka. Wybór metod oceny ryzyka ma wpływ na dokładność i rzetelność rezultatów wykorzystanych w procesie podejmowania decyzji zarządczych, związanych przede wszystkim z wyborem strategii i metod zarządzania ryzykiem.

Rozważania zawarte w niniejszym artykule stanowią przegląd metodologiczny narzędzi zarządzania ryzykiem w przedsiębiorstwie. Dodatkowo, w artykule zostały zaprezentowane możliwości i zakres wykorzystania tych narzędzi w przedsiębiorstwach górniczych.