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RETRACTED: Implementation of Stochastic Analysis in Corporate Decision-Making Models

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Abstract: The stochastic approach as a method for modeling factor systems of interrelationships of economic activity aspects allows minimizing managerial errors against the background of company growth and expansion of operating activities. The purpose of this study is to form a decision-making model to ensure the financial competitiveness of enterprises in the context of stochastic analysis. This study demonstrates stochastic analysis implementation in companies of the 2nd and 3rd degrees of internationalization based on multiple regression and factorial analysis of variance. The practical basis of the study was Chinese and Russian trading enterprises that enter highly competitive markets and therefore should avoid mistakes in decision-making as much as possible. The model of financial competitiveness proposed in the article demonstrates the best ways to introduce stochastics in companies to optimize their overall productivity, regardless of the country of origin. In a practical sense, research on reducing managerial mistakes allows enterprises to have financial success even in the turbulent conditions of today's global market, regardless of the company's jurisdiction.

Keywords: analysis of variance; financial competitiveness; management; multiple regression; risk

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1. Introduction

The key issue of ensuring the optimal operation of a modern enterprise in competitive market conditions is increasing the efficiency of its economic activities. The need to assess the efficiency of an enterprise's activity is due to the need for the formation of new goals, principles, and foundations of management focused on meeting consumer needs and market requirements. Evaluation of production processes' efficiency is an integrated system of enterprise development goals; this system covers a number of factors and activities that determine the level of production organization. Management decisions, in this case, pursue the goal of production rationalization under certain labor, technical, and technological conditions. These decisions focus on enterprise's operation efficiency without unpredictable and significant costs [1]. The economic behavior of business entities should be unique at each stage of the life cycle. Taking into account the peculiarities of business entities' activities at each stage should contribute to a determination of the appropriate strategy and the construction of an effective combination of tactics for its implementation [2]. Therefore, for the successful management of an enterprise, an important task is the search for new tools, methods, and approaches to modeling its economic behavior, taking into account the dynamic characteristics of the economic system [3].

Efficiency analysis occupies an important place in an enterprise's management system since it is an effective tool for information and analytical support of an enterprise. The

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assessment results form the basis for making management decisions, while they can be used both to determine strategic and tactical goals [4,5]. This study is intended to become a conceptual basis for assessing an enterprise's efficiency in the context of financial competitiveness and rational management decisions based on stochastics.

Mining enterprises were selected to study the effectiveness of decisions made in the conditions of risk. Since today the products of mining enterprises are scarce, which is associated with the need to build roads, their production processes can be attributed to complex unstructured and informal objects of making managerial decisions [6]. That is why the results of this study (aimed at modeling management decisions for solving problems using stochastics) should contribute to the advancement of financial, production, and investment processes of mining enterprises.

Stochasticity is one of the properties of the environment for the functioning of economic systems such as enterprises. Since any organization is an open system, it is influenced by the external business environment. Such impacts can be unpredictable (in particular, force majeure) and lead to uncontrolled changes in company activities [7]. Stochastic factor analysis is a method for solving a wide range of statistical estimation problems. It provides for the study of massive empirical data by building models of changes in indicators due to factors that are not in direct interdependence [8]. In business analysis, the following most common tasks of stochastic analysis can be distinguished:

- The study of the relationship between the function and factors.
- Classification of factors of economic effects.
- Determination of an analytical relationship between processes under consideration.
- Identification of parameters of regular periodic fluctuations in the level of key indicators.
- Study of quantitative changes in the influence of factors on indicators.
- Economic interpretation of the obtained analytical dependencies [9].

Most often, when conducting stochastic analysis, modeling of economic activity is used, especially if it is possible to compare the set of observations [10]. Modeling is carried out using techniques of mathematical statistics, which allow investigating indirect causal relationships of economic activity indicators with production indicators and parameters. With the help of these methods, it is possible to determine not a functional, but a stochastic causal relationship between economic phenomena, that is, one can study the factors that have a tendentious effect on the object of research [11].

When modeling the plan of a certain economic object, characterized by both internal and external uncertainty, it is inappropriate to limit stochastic programming. This is also typical when solving the problem of effective management of mining production by individual companies. This prompts the imposition of less stringent conditions, namely the introduction of the assumption that the constraints are not met with a certain probability and the concept of the risk of a short-term forecast. This approach to modeling stochastic processes corresponds to the idea of introducing risk in planning the production of mining products, carried out in conditions of uncertainty in both the internal and external business environment of an enterprise, where a certain parameter can quantitatively express the amount of risk [12].

Solving the problem of effective mining management by individual plants is advisable in the context of stochastic programming since such a company, when implementing any solution to a problem, will have a certain percentage of the risk of its use [13]. This involves the identification of production, financial, and economic risks, monitoring, analysis, and assessment of these risks, the development of strategic and tactical plans for managing production and economic risks, taking into account the results of current planning [14]. It is also necessary to detail the procedures and implement the process of managing production, economic, and financial risks [15].

The production and economic activity of mining enterprises in their market space are constantly associated with such key factors as the price and quality of products. Therefore, when forming a strategy for the economic development of mining enterprises, more attention should be paid to reference (basic) business strategies [16]. At the same time, considerable attention should be paid to export assistance strategies to minimize the risks [17]. All this can increase the ability of the management of mining enterprises to prevent potential risks in advance and develop appropriate measures aimed at reducing them to the minimum acceptable levels.

The primary task of the management of mining enterprises should be focused on the choice of enterprise strategies, which are the basic modern business structures. Mining enterprises should always assess their strategic potential, which is understood as the totality of economic resources and production capabilities of an enterprise. They can be used to achieve the goals of a production enterprise, taking into account economic risks [18]. Timely identification of financial stability and conditions to which financial risk can lead makes it possible to timely prevent undesirable consequences, choose a more flexible strategy [19]. In the case of confirmation (verification) with the help of quantitative assessments of efficiency and riskiness indicators, it becomes possible to form reliable forecasts regarding future activities and plan economic results [20]. Thus, it is advisable to analyze the financial stability of an enterprise itself, as well as projects and strategies implemented by it, as well as perform a comparative analysis of the riskiness of activities within the market segment, industry, country, etc. [21,22]. At the same time, adequate measures in the field of formation of state policy for the rational development of specific types of mineral raw materials are important; namely, individual raw materials groups should be defined according to their strategic importance for both national and regional industries [23].

Mining enterprises, as economic entities with high technological inertia and a large-scale production structure, require significant investments to support their sustainable functioning. Effective distribution of investments in key areas of investment activities of such enterprises in the existing conditions requires the use of modern economic and mathematical methods and models. It is advisable to put the tools of economic and mathematical modeling at the basis of the process of monitoring the opportunities and threats to the functioning of mining enterprises. As a result of constant analytical developments, taking into account the modeling of economic risks, it is advisable to form scientifically grounded strategic guidelines for the development of mining enterprises in the context of globalization [24,25]. Thus, today, there is an objective need for the formation of mining companies' corporate decision-making models in turbulent conditions. This study aims to fill this gap by developing a methodological approach to modeling and assessing the level of risks of mining companies. Therefore, the purpose of this study is to form a decision-making model to ensure the financial competitiveness of enterprises in the context of stochastic analysis. To achieve this goal, the following tasks were solved:

- Regression models of financial competitiveness were formed for the mining companies under study.
- The indicators and possible deviations from mining companies' level of financial competitiveness were determined.
- Analysis of variance (ANOVA) of factors' influence in the financial competitiveness model was carried out.
- The level of influence of the factors included (and not included) in the model on its performance in the companies under study was identified.
- A comparative description of the results obtained before and after the introduction of stochastics into the decision-making model of mining companies was carried out.

2. Materials and Methods

The study is based on modeling management decisions of a mining enterprise in the context of stochastic analysis. If x–an alternative set of X production processes $x \in X$, then for it, one can set $\Im(x)$–quality criterion (objective function, utility function), for which two sets of alternatives can be distinguished X_1; X_2, when the alternative X_1 is better than X_2, that is $X_1 > X_2$, then $\Im\,(X_1) > I\,(X_2)$. The choice of any alternative leads to ambiguously known consequences, where the best alternative $\hat{X}_H$ was the one that had the best value of the quality criterion for assessing the distance between classes:

$$\hat{X}_H = arg\ max\ \Im(x), \tag{1}$$

where $\Im\ (x)$–the maximum values of the quality criterion of the range of admissible values of strategies x. On the variables X and arrays of fixed non-random parameters C the following values of the constraint function are superimposed:

$$g = g\ (A, X)\ \{\leq, =, \geq\}\ b, \tag{2}$$

where g is the restriction function and b the specific numerical values of restrictions. In other tasks of production processes, the search for $\hat{X}_H$ was very complex, multi-criteria and depended on a function or functionality $\Im(x)$. In the production processes of mining enterprises, there is a need to consider a set of problems, the solution of which can also provide a solution to a general problem. In turn, each task is also quite difficult. To solve it, a multi-layered approach was used [26].

When creating models of management decisions of mining enterprises, management problems arise at the level of elements, subsystems, and the system as a whole. For example, models of management decisions under conditions of uncertainty and risk. The lower-level models with one-criterion connection have a strict mathematical formulation of decision-making process (DMP). Here, the control efficiency is determined by the numerical optimality criterion:

$$\Im = \Im(X, C). \tag{3}$$

The constraint function looks like (4):

$$g_j = g_j(A_j,\ X)\{\leq, =, \geq\}\ b_j,\ j = \overline{1,\ m}\,, \tag{4}$$

where $X = \{X_i\},\ i = \overline{1, n}$ – vector of well-defined strategies; C is an array of fixed non-random factors; A_j is an array of fixed non-random parameters; $A_j,\ C$ isaccepted if known. The goal of the operating party is to maximize the optimality criterion:

$$\Im = \Im(X, C) \rightarrow max. \tag{5}$$

By selecting such best strategy estimates $\hat{X} = \{X_i\},\ i = \overline{1, n}$ vector $X = \{X_i\},\ i = \overline{1, n}$ out of range Ω_X so that:

$$\overline{\Im} = \Im(\hat{X}, C) = max\ \Im(X, C),\ X \in \Omega_X. \tag{6}$$

This DMP formulation fully coincides with the general formulation of mathematical programming (MP):

$$\begin{cases} \Im(X) \rightarrow \max(\min); \\ g_j(X)\{\leq, =, \geq\}\ b_j,\ j = \overline{1,\ m}\,. \end{cases} \tag{7}$$

$\hat{X} = \{X_i\},\ i = \overline{1, n}$–n-dimensional vector of problem variables. As it is known, a significant number of methods are used to solve MP problems. For an applied object of production processes of a mining enterprise, this study has tested the methods of linear and nonlinear programming in deterministic and stochastic forms. Multiple regression models were formed for each investigated enterprise and a stochastic ANOVA of the influence of models' components was carried out. In conditions of risk, ANOVA methods and financial competitiveness forecasts are used.

In general, the operating party's strategy, $X_i,\ i = \overline{1, n}$ can be a scalar, vector, matrix, or even more complex formation. It is assumed that the strategy $X = (X_1, X_1, \ldots X_n)$ is an n-dimensional vector. Components X_i are associated with the production processes of a mining enterprise as follows:

$$G_j = G_j(C_j, X) \geq b_j,\ j = \overline{1,\ m}\,, \tag{8}$$

where G_j–vector function of technological constraints; b_j–specific values of technological constraints; C_j–set of non-random factors.

Condition (8) determines the area of admissible strategies Ω_X, that is, from this area, the decision maker (DM) chooses strategies in this situation.

The effectiveness of operating party actions is evaluated by a set of local criteria: $\Im_{\lambda 1},\ \Im_{\lambda 2},\ \ldots \Im_{\lambda k}$, which have corresponding weights $\lambda 1,\ \lambda 2,\ \ldots \lambda k$. Then there are two vectors $\Lambda = \lambda_j,\ j = \overline{1,k},\ \overline{\Im} = \Im_j,\ j = \overline{1,k}$. Each component of the criterion $\overline{\Im}$ characterizes the local goal of the operation and is related to the strategy, which can be displayed as follows:

$$\Im_j = \Im_j(A_j, X),\ j = \overline{1,k}, \tag{9}$$

where A_j–set of fixed parameters.

Partial display $X \to \Im_j$ is the functional relationship between the criterion $\Im_j$ and strategy X. The simultaneous achievement of the goal of the operation for all local criteria with one strategy is impossible, therefore the solution consists in finding a compromise in achieving local goals. Then the following problem arises: strategy X_{opt} must belong to the set Ω_X of its valid values; the strategy should be the best relative to the accepted principle of compromise taking into account the vector Λ of the importance of the criteria:

$$\Im_{opt} = \Im(X_{opt}) = \underset{X \in \Omega_X}{opt}\ [\Im(X), \Lambda]. \tag{10}$$

Operator opt determines the principle of optimality, the choice of the best solution. Optimality principle-mathematical model of the compromise principle.

Region Ω_X can be divided like this: Ω_X^a–the area of agreement where a solution can be improved simultaneously on all indicators; Ω_X^c–the area of compromises, in which an improvement in the quality of a solution according to some local criteria leads to deterioration in the quality of a solution according to others. The optimal solution belongs to the area of compromise Ω_X^c. To justify the solution, it is necessary to disclose the operator opt to search for a compromise scheme. When analyzing a compromise scheme, it is assumed that local criteria are normalized and are of equal importance. Using the area of admissible criteria, the following can be written:

$$\Im_{opt} = \Im(X_{opt}) = \underset{X \in \Omega_X}{opt}\ [\Im(X), \Lambda] = \underset{\Im \in \Omega_{\Im}^K}{opt}\ [\Im, \Lambda]. \tag{11}$$

In a situation of uncertainty, one of the parties can be defined as a business environment which cannot be assigned deliberate tasks. However, a researcher gradually studies the environment and reduces uncertainties [10]. In DMP, the "game with the business environment" is formalized as follows: the DM chooses one of n possible strategies x_j, $i = \overline{1,n}$; operation result, $s_j,\ j = \overline{1,m}$ will look like: A–DM's gain, $\overline{A}$ –DM's loss. Then the matrices of gains and losses will have the form:

$$A = |a_{ij}|; \overline{A} = |\overline{a}_{ij}|. \tag{12}$$

Using gain and loss matrices (12), one can obtain the corresponding gain and loss functions:

$$a_{ij} = A(x_i, s_j);\ \overline{a}_{ij} = \overline{A}\,(x_i, s_j), \tag{13}$$

If one fixes the value of strategies x_f^i at the appropriate steps, then instead of functions (13) with two arguments, one gets risk functions with one argument. Then the risk function using the example of determining losses will look like this:

$$r\left(x_f^i\right) = P\overline{A}^i\left(x_f^i, s_j\right), \tag{14}$$

where $r\left(x_f^i\right)$–risk associated with the strategy x_f^i; P–functional by which the loss function $\overline{A}^i$ turns into a risk function. Then the best strategy is $x^* \in X$, which minimizes the risk on the set X:

$$r(x^*) = \min_{x_i \in X} r(x_i), i = \overline{1, n}. \tag{15}$$

For mining enterprises, financial competitiveness plays an important role, therefore, in the methodology of this study, a model is presented that can become a significant addition to making management decisions. The main indicators on which the study is based are four integral indicators: the effectiveness of financial and economic activities (CE_f); cost of business processes (VE_{bp}), indicator of financial stability of production support (CE_{pr}), activation of financial (investment) management (ME_{inv}). Based on these indicators for 2015–2019, multiple regression equations were formed for each surveyed enterprise.

To assess the level of financial competitiveness of a mining enterprise using the indicated indicators, its change is presented in the form of a differential:

$$\begin{aligned} FC' = \sum_{i=1}^{n}\left(\frac{\partial FC}{\partial CE_f} dCE_f + \frac{\partial FC}{\partial VE_{bp}} dVE_{bp} + \frac{\partial FC}{\partial CE_{pr}} dCE_{pr} + \frac{\partial FC}{\partial ME_{inv}} dME_{inv}\right) = \\ = \sum_{i=1}^{n}(FC_f + FC_{bp} + FC_{pr} + FC_{inv}), \end{aligned} \tag{16}$$

where FC_f is the financial competitiveness of an enterprise, which depends on the level of its financial and economic activities; FC_{bp} the financial competitiveness of a company, which depends on the cost of business processes; FC_{pr} is the financial competitiveness of a company, which depends on production activities; FC_{inv} is the financial competitiveness of an enterprise, which depends on financial (investment) management.

To build the first component of the corporate decision-making model, the value of the ratio of changes in financial competitiveness to changes in the efficiency of financial and economic activities was set (FC_f) in the range from 0–1. The relationship between the level of this ratio and the level of the indicator of a company's performance (CE_f) is determined by the coefficient β_{1i}. The value of this coefficient varies: $0 \leq \beta_{1i} \leq 1$. Sum of coefficients β_n equals to 1. By introducing this coefficient, one gets:

$$\frac{\partial FC_q}{\partial CE_f} = \beta_{1i} CE_f, \tag{17}$$

Thus, one gets:

$$FC_q = \sum_{i=1}^{n} \beta_{1i} \int CE_f \partial CE_f = \sum_{i=1}^{n} \beta_{1i} \int \left(\frac{{CE_f}^2}{2} + r_{CE_f}\right) \tag{18}$$

r_{CE_f} is equal to 0 since this is an arbitrary constant.

For each researched business entity, the rate of change in the level of financial competitiveness will be inversely proportional to the cost of business processes. Moreover, with an increase in the cost of business processes, a decrease in financial competitiveness will be observed. The indicator of the cost of business processes is determined as follows:

$${VE_{bp}}_i^w = 1 - \frac{VE_{bpi}}{\sum_{i=1}^{n} VE_{bpi}}, \tag{19}$$

$$0 < VE_{bp}{}_i^w < 1,$$

where $VE_{bp}{}_i^w$–the relative share of the cost of i-th business process; VE_{bpi} –the cost of *i*-th business process, $\sum_{i=1}^{n} VE_{bpi}$ –the sum of the cost of homogeneous business processes used for research.

As a result of the introduction of the coefficient β_{2i}, one will get:

$$\frac{\partial FC_{bp}}{\partial VE_{bp}} = \frac{-\beta_{2i}}{VE_{bp}}, \quad (20)$$

Thus, one gets:

$$FC_{bp} = \sum_{i=1}^{n} \beta_{2i} \int \frac{-dVE_{bp}}{VE_{bp}} = \sum_{i=1}^{n} \beta_{2i} \left(-\ln VE_{bp} + r_{VE_{bp}}\right), \quad (21)$$

wherein: $0 \leq \beta_{2i} \leq 1$, while $r_{VE_{bp}}$ is equal to 0 since this is an arbitrary constant.

The ratio of the change in the level of a company's financial competitiveness, depending on its production activities, to the change in the level of financial support of production activities, characterizes an enterprise's productivity during time t. The efficiency of an enterprise in this context can be assessed using the following formula:

$$CE_{pr} = \frac{AP}{C}, \quad (22)$$

where AP is an additional income of an enterprise from improving the efficiency of production activities and TC the costs of the enterprise during production activities. By introducing the coefficient β3i, the value of which is in the range from 0–1, one obtains:

$$\frac{\partial FC_{pr}}{\partial CE_{pr}} = \beta_{3i} CE_{pr} \quad (23)$$

$$FC_{pr} = \sum_{i=1}^{n} \beta_{3i} \int CE_{pr} \partial CE_{pr} = \sum_{i=1}^{n} \beta_{3i} \int \left(\frac{CE_{pr}{}^2}{2} + r_{CE_{pr}}\right), \quad (24)$$

$r_{CE_{pr}}$, similarly to the previous cases, equals 0 since it is an arbitrary constant.

There is an inverse relationship between the rate of change in the financial competitiveness of an enterprise and a change in the investment component. The ratio of the change in company's financial competitiveness, depending on a company's investment activity (ME_{inv}), to the change in the efficiency of a company's investment activity is approximately equal to the negative value of the inverse indicator of company's functioning efficiency. By introducing the coefficient β_{4i}, the value of which is in the range $0 \leq \beta_{4i} \leq 1$, one obtains:

$$\frac{\partial FC_{inv}}{\partial ME_{inv}} = \frac{-\beta_{4i}}{ME_{inv}} \quad (25)$$

$$FC_{inv} = \sum_{i=1}^{n} \beta_{4i} \int \frac{-dME_{inv}}{ME_{inv}} = \sum_{i=1}^{n} \beta_{4i} \left(-\ln ME_{inv} + r_{ME_{inv}}\right), \quad (26)$$

r_{EAstr} , similar to the previous cases, is equal to 0 since it is an arbitrary constant.

Having determined the components of calculating the financial competitiveness of an enterprise, it is possible to build a corporate decision-making model, which, taking into account the above, has the following form:

$$\begin{aligned} CDM &= \sum_{i=1}^{n} \beta_{1i} \int \frac{CE_{fi}^2}{2} - \sum_{i=1}^{n} \beta_{2i} \ln VE_{bp} + \sum_{i=1}^{n} \beta_{3i} \int \frac{CE_{pri}^2}{2} - \sum_{i=1}^{n} \beta_{4i} \ln ME_{inv}, \\ CDM &= \sum_{i=1}^{n} \left(\frac{\beta_{1i} CE_{fi}^2}{2} - \beta_{2i} \ln VE_{bp} + \frac{\beta_{3i}\, CE_{pri}{}^2}{2} - \beta_{4i} \ln ME_{inv}\right) \end{aligned} \quad (27)$$

The resulting model makes it possible to determine the level of financial competitiveness of an enterprise depending on four important components of the efficiency of its functioning.

In the final part of the study, general characteristics of the possibility of using the proposed model of financial competitiveness for the production processes of mining enterprises are given: maximin, maximax, extreme (optimism and pessimism), minimax, mathematical expectation, the best option for equal opportunities, mean value, and standard deviation.

The study was based on materials from 10 mining enterprises: 5 companies from the Russian Federation (A, B, C, D, E) and 5 companies from China (F, G, H, I, J). The main selection criterion was that companies belong to the 2nd and 3rd degree of internationalization since they enter highly competitive markets and therefore should avoid mistakes in decision making as much as possible. Among the parameters for selecting companies were the following: annual sales of products-15–25 million US dollars; product profitability not less than 18%; history of functioning from 30 to 50 years. These parameters contributed to the analysis of companies from two countries in order to provide an opportunity to compare them with each other. The choice of companies in China and Russia is based on the fact that these countries are leaders in the global mining industry and key players in the market. China is the largest consumer in the industry, and Russia is the largest mining country with the most significant subsoil resources. For these countries, the mining industry is of strategic importance; therefore, the selected companies are partially owned by a government.

3. Results

In order to model the predicted values in the future, based on the research of the variables that make up the decision-making model proposed in this study, multiple regression equations were formed for each investigated enterprise (Table 1). Moreover, these regression models are reliable. This is confirmed by R^2 values, which are at a fairly high level (from 0.88 to 0.97), that is, close to 1. This indicates a close relationship between the variables and the resulting indicator-the level of financial competitiveness. Herein $F > F_{crit}$, which also characterizes the formed regression models from the positive side, indicating their applicability.

Table 1. Regression models of the level of financial competitiveness for the studied mining companies.

Enterprise	Multiple Regression Equation	R^2	F	F_{crit}
A	$Y = 0.1954 + 3.9329\ X_1 - 1.7583\ X_2 - 1.2623\ X_3 + 0.0018\ X_4$	0.93	224.58	4.45
B	$Y = 0.7834 + 8.5438\ X_1 - 4.3796\ X_2 - 2.9106\ X_3 + 0.0074\ X_4$	0.95	685.29	3.58
C	$Y = 0.3783 + 2.5528\ X_1 - 1.6529\ X_2 - 1.1283\ X_3 + 0.0026\ X_4$	0.95	451.48	4.22
D	$Y = 0.1614 + 1.5042\ X_1 - 1.8426\ X_2 - 1.4269\ X_3 + 0.0012\ X_4$	0.97	186.51	1.68
E	$Y = 0.6917 + 9.5829\ X_1 - 1.7649\ X_2 - 1.3599\ X_3 + 0.0047\ X_4$	0.89	549.38	3.49
F	$Y = 0.5429 + 4.4836\ X_1 - 2.1942\ X_2 - 1.6825\ X_3 + 0.0056\ X_4$	0.91	486.91	2.85
G	$Y = 0.7032 + 4.0538\ X_1 - 2.6722\ X_2 - 1.9912\ X_3 + 0.0068\ X_4$	0.88	601.39	3.27
H	$Y = 0.4626 + 1.8743\ X_1 - 1.4582\ X_2 - 1.1649\ X_3 + 0.0033\ X_4$	0.97	492.45	4.85
I	$Y = 0.1928 + 2.5625\ X_1 - 1.2671\ X_2 - 1.7563\ X_3 + 0.0027\ X_4$	0.94	218.25	4.06
J	$Y = 0.2665 + 5.1487\ X_1 - 2.1305\ X_2 - 2.1988\ X_3 + 0.0036\ X_4$	0.95	345.29	4.82

Source: generated by the authors.

The closest relationship between variables and financial competitiveness is characteristic of companies D, H, B, C, J. Thus, it can be argued that for half of the mining companies under study, most of which are Russian, the proposed factors affect the level of financial competitiveness at a level above 95%. These factors include efficiency of financial and economic activities, cost of business processes, an indicator of financial solvency to ensure production activities, investment activity.

Using these models, indicators of the level of financial competitiveness for the companies under study were predicted (Figure 1). At the same time, deviations from the predicted result were determined on the basis of expected value and variance.

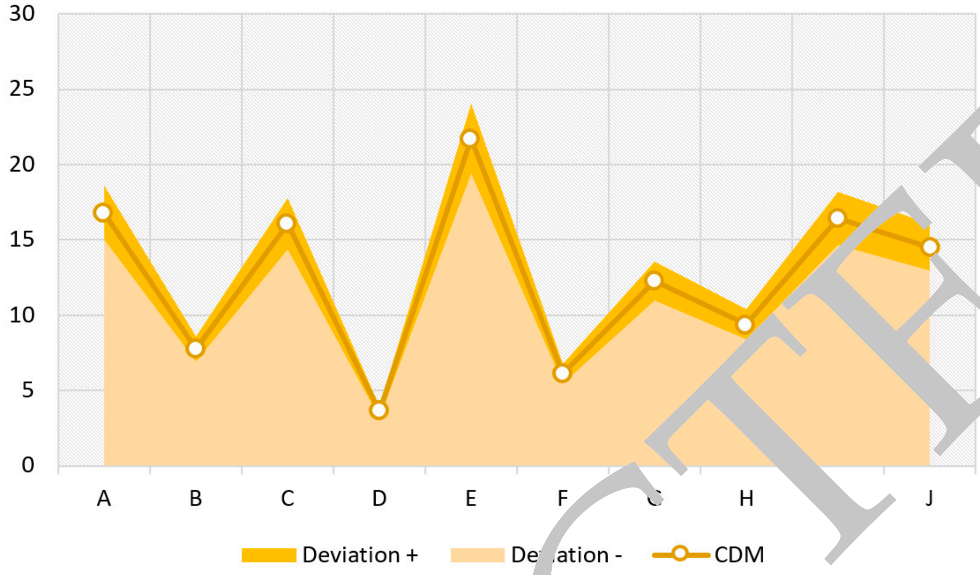

Figure 1. Forecasted indicators of financial competitiveness level of the surveyed companies (CDM) for 2021. Source: generated by the authors.

The highest level of financial competitiveness was recorded in companies E, A, C, I, that is, mainly in Russian companies. This result was facilitated by the developed components of the corporate decision-making model in the context of financial competitiveness. For example, for Company E, the high level of financial competitiveness was promoted by financial [illegible]ncy to support production activities. For companies A, C, I, the key component of the model is the efficiency of financial and economic activities. All companies under study are characterized by possible deviations from the forecasted results. Considering that the coefficient of variation is 11%, the largest volumes of deviations, including negative consequences, may be in the leaders in terms of financial competitiveness. However, in general, a fairly high level of risk is present in the activities of all the companies under study. Therefore, additional research is needed on the degree of influence of certain risks. It is implemented in this study in the form of ANOVA of the influence of factors proposed in financial competitiveness model on a company's performance. A fragment of this analysis for company A is shown in Table 2.

Table 2. ANOVA indicators for the influence of factors proposed in financial competitiveness model (fragment, company A).

Source of Variation	SS	df	MS	F	*p*-Value	F Statistic
CE_f	36.3239	2	18.1619	257.0253	0.0000	3.4028
β_{1-4}	0.0942	3	0.0314	0.4443	0.7236	3.0088
Interaction	0.0166	6	0.0028	0.0392	0.9997	[illegible]
VE_{bp}	0.0313	2	0.0157	88.7257	0.0000	3.4028
β_{1-4}	0.0939	3	0.0313	177.3221	0.0000	3.0088
Interaction	0.0000	6	0.0000	0.0135	[illegible]	2.5082
CE_{pr}	0.0060	2	0.0030	88.7257	0.0000	3.4028
β_{1-4}	0.0941	3	0.0314	922.1234	0.0000	3.0088
Interaction	0.0000	6	0.0000	0.0135	1.0000	2.5082
ME_{inv}	0.0000	2	0.0000	88.7257	0.0000	[illegible]
β_{1-4}	0.0942	3	0.0314	[illegible]	0.0000	3.0088
Interaction	0.0000	6	0.0000	0.0135	1.0000	2.5082

Source: generated by the authors.

ANOVA demonstrates a high degree of influence of the constituent components of the financial competitiveness model on the level of efficiency of the corporate decision-making model, including for the rest of the studied companies. This is confirmed by a *p*-value below 0.05. At the same time, there is an absence of the influence of their share in the formation of model functioning effectiveness. However, there are still unaccounted for factors that can affect model's effectiveness and increase the likelihood of risks in enterprise's activities. Moreover, the degree of their influence on each mining enterprise is different. Based on the ANOVA carried out, the influence of factors included in the proposed financial competitiveness model as well as unaccounted risk factors was identified (Figure 2).

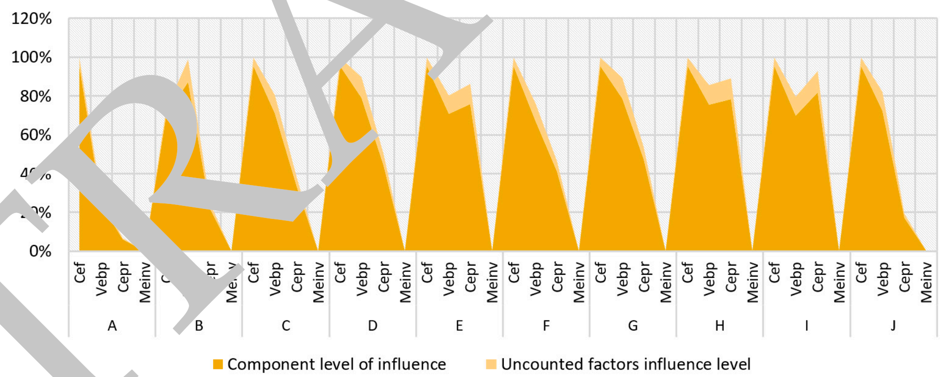

Figure 2. The level of influence of factors included in the model (and those not included) on its performance in the companies under study. Source: generated by the authors.

It is not possible that absolutely identical risk characteristics exist for the studied mining companies. This is quite logical since each enterprise has its own specifics, results, and conditions of the business environment. It can be noted that for the majority, such components of the model as the cost of business processes and financial solvency for ensuring production activities play a special role. Among the studied mining companies, one can single out those that have a level of risk influence of more than 10%. In terms of the cost of business processes, these include companies B, C, D, G, H, J. Thus, for most Russian and Chinese mining companies, minimizing the risks of managing business processes is relevant. In terms of financial solvency, high risk is present in Chinese companies I, H, J. Risks for other indicators are below 10%. The lowest level of risks for all components of the model is observed in Russian company A. This is a consequence of the company's foreign economic activities and partnerships, which have the highest level of influence on the performance of model components, which minimize the impact of risks in the context of unaccounted factors.

Based on the identification of critical points for each surveyed enterprise through feedback, recommendations were formed for the development of one or another component of the model. As a result of repeated forecasting of the performance of the proposed model, taking into account the stochastic analysis of variance, updated data were obtained (Figure 3).

Stochastic factor ANOVA contributed not only to an increase in the level of efficiency of the proposed model of financial competitiveness but also to a decrease in possible deviations for all mining companies. At the same time, there is no significant difference in the results obtained between companies representing different countries. The coefficient of variation decreased from 11% to 7%. Thus, it can be argued that the proposed model of financial competitiveness demonstrates the best ways to introduce stochastics into work cycles in order to optimize the overall performance of a company, regardless of a country in which a company operates (Figure 4).

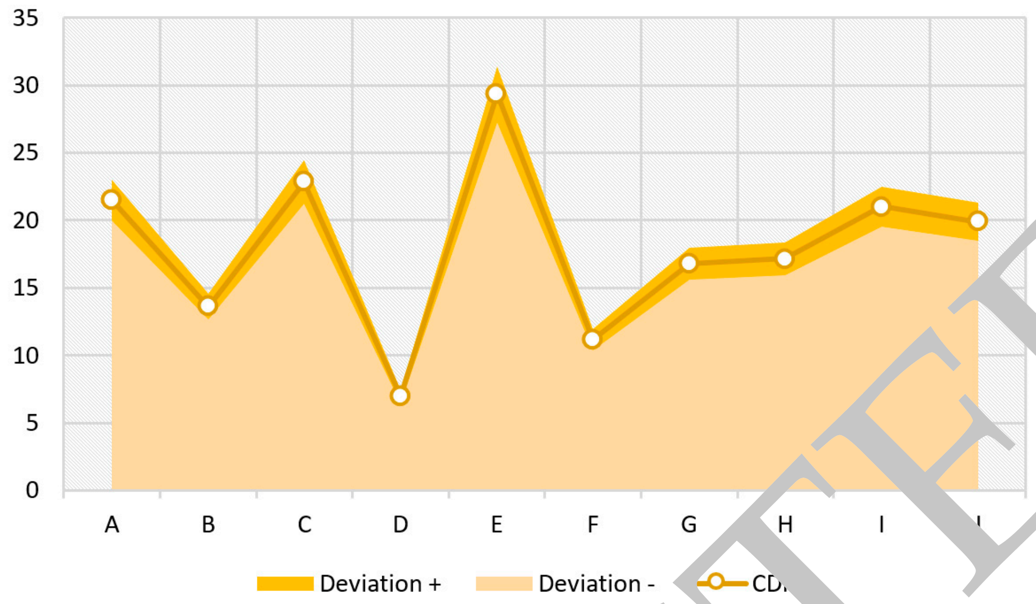

Figure 3. Indicators of the level of financial competitiveness of the companies under study in 2021 as a result of using stochastic analysis. Source: generated by the authors.

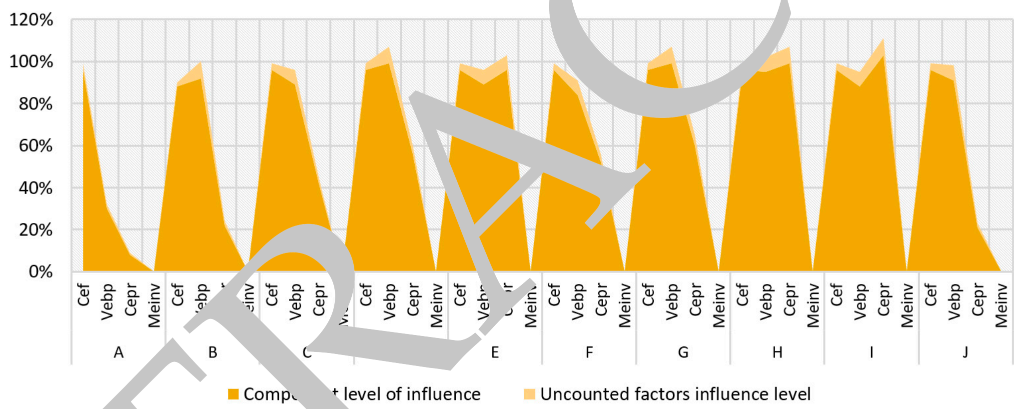

Figure 4. The level of influence of factors included (and not included) in the model on its performance in the companies under study. Source: generated by the authors.

Thanks to the introduction of stochastics into the financial competitiveness model, it seems possible to minimize the previously identified level of risks for the above companies below 8%. At the same time, there is a decrease in possible deviations from the predicted results formed at the initial stage (Figure 5).

The majority of the mining companies under study are characterized by a decrease in the coefficient of variation and corresponding deviations. If one compares the results before the stochastic factorial ANOVA and after its use, one can notice that the deviation for some companies (B, D, F, H) is increasing. However, this is not a negative characteristic of the proposed approach, since it also influenced the performance of the model as a whole. Therefore, in relative terms, the deviations of these companies are significantly lower than before stochastics were used.

This study indicates the need to use stochastics in the management decision-making processes of an enterprise, and also confirms the effectiveness of the implementation of the proposed model of financial competitiveness in the context of the introduction of stochastic analysis for mining companies, regardless of a country and region of its operation.

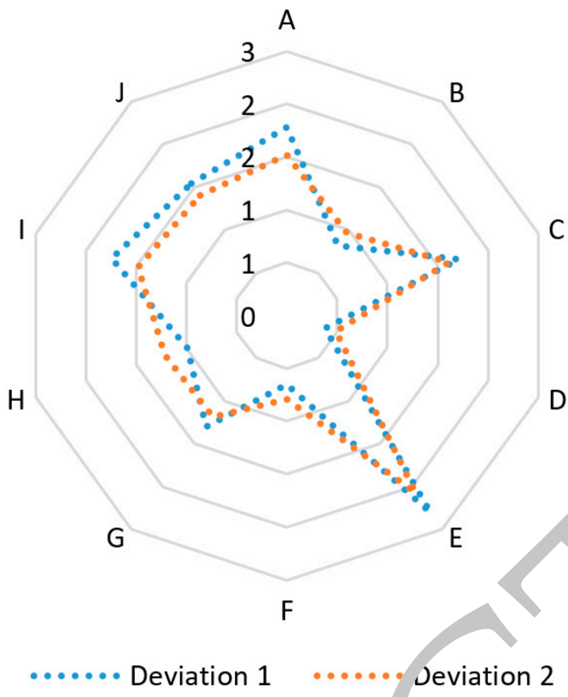

Figure 5. Deviations from the planned level of financial competitiveness before and after using the corporate decision-making model. Source: generated by the authors.

4. Discussion

Taking into account mining enterprises' peculiarities, this study defines the roles of subsystems (subfactors) in the framework of a comprehensive assessment of the level of financial competitiveness and the formation of its model. The top-level element always deals with larger subsystems or broader aspects of an enterprise as a whole. Descriptions and objectives at the upper levels are less structured, have more uncertainties, and are difficult to quantify. Decision-making tasks at higher levels are more difficult [27].

The proposed methodological approach takes into account that the low level of certainty of the studied objects is dictated by many factors that are of a stochastic nature. The model proposed in the study considers mining companies that function under conditions of uncertainty, where the result depends on uncertain factors that are unknown at the time of decision making and do not depend on the operating party. Therefore, each strategy of the operating side corresponds to a certain set of possible results [28]. Moreover, unknown factors appear due to insufficient information about their internal and external nature and origin. The advantage of the study is that it takes into account the uncertainty of factors and non-stochastic origin. For example, strategic uncertainties, in which several operating parties are involved in an operation with different goals, and each party makes a decision when the actions of other participants are unknown [29]. In the formation of the proposed model, conceptual uncertainties were used, when uncertain factors for especially difficult decisions based on long-term results are identified on the basis of stochastic ANOVA, fuzzy ideas about the goals of other participants [30]. However, in this case, a conflict situation may also arise, for the analysis of which it is advisable to use the theory of games and the theory of the minimax. The following prerequisites are associated with this: each company knows the goals and strategies of others and each company has an active business position. Therefore, the determining factor in its behavior is the maximum achievement of its own goals [31].

Depending on specific situations, the model of decision making proposed in the study in conditions of uncertain situations of production processes of mining enterprises, in the future, can be built on expanding the group of criteria. For example, the maximin test (Wald test) focuses on the best of the worst results. In this case, the company is minimally ready for risk, it does not want to win so much as not to lose, and this is the criterion of a pessimist. The maximax criterion corresponds to an optimistic offensive strategy. The Hurwitz criterion provides for an evaluative function between the views of extreme optimism and extreme pessimism. The decisive factor here is the parameter of the investor's confidence in obtaining the maximum benefit. The minimax criterion (Savage criterion) focuses on minimizing lost profits and involves a reasonable risk in order to get additional profits. The expected value criterion (Bayesian criterion) is based on the assumption that the probabilities of the occurrence of possible states of the external business environment are known. The mean and standard deviation criterion is used to assess a mean predicted value of the criterion. The higher the standard deviation, the greater the risk. Laplace's criterion allows one to separate the best option in the case when none of the conditions has a significant advantage. This assumes that the probability of each of the possible states of the business environment is the same [32–34].

The advantage of the proposed methodological approach is the substantiation of the choice problem, which presupposes a plurality of the studied tasks:

- selection and evaluation of alternatives according to one or several criteria;
- a single or multiple-choice mode;
- a choice under certainty conditions;
- a choice under conditions of a probabilistic nature;
- a choice under conditions of uncertainty;
- individual or group responsibility for the consequences of choice;
- the degree of consistency of goals in group choice;
- assessment of the consequences of choice in growing group conflicts [35].

Moreover, for normal conditions of modeling object functioning, this object can be attributed to objects with certain consequences, and for conditions of conflict, an object can fall into conditions of uncertainty.

The limitation of this study is the assumption of the dependence of financial competitiveness on the cost (quality) of business processes, considering other factors unchanged. The rate of change in the financial competitiveness of an enterprise is directly proportional to the change in product quality, and directly depends on the quality of business processes [4,36]. An increase in the quality indicator of business processes with an increase in the level of financial competitiveness of the model proposed in the study occurs because, as a rule, higher quality products are more attractive on the market, all other things being equal between mining companies [37], and, accordingly, such products should have a larger market share [38].

In the future, this study may have an expansion in the number of companies under study, industries, as well as countries and regions. At the same time, the range of research can be supplemented by the environmental and social components of the development of companies, by assessing the impact of the efficiency of mining enterprises on the performance of a country's economy [39]. This study can be useful for top managers and those responsible for the economic security of a business when forming strategic intentions and monitoring their achievement.

5. Conclusions

Based on study results, for the complex, unstructured, and informal production processes of mining enterprises, the components of a conceptual model of management decisions have been developed and formed by dividing a general problem into a number of investigated components: separation of a set of alternatives, choice under conditions of a stochastic nature, strategic and conceptual uncertainty.

On the basis of formed regression models of financial competitiveness level for mining companies under study, a close relationship was revealed between such variables as the efficiency of financial and economic activities, the cost of business processes, financial solvency for ensuring production activities, investment activity, and financial competitiveness. At the same time, for half of the mining companies studied, the proposed constituent factors of the model affect the level of financial competitiveness at a level approaching 1.

An additional study based on ANOVA of the factors proposed in the financial competitiveness model showed their high degree of influence on the final result. Assessment of the influence of factors included (and not included) in the model on its performance in the studied companies characterizes a high level of risk of the cost of business processes and financial solvency for ensuring production activities. Stochastic factor ANOVA made it possible to identify companies with the maximum level of risk and determine its causes. At the same time, stochastic factor ANOVA became the basis for determining the directions for increasing the level of efficiency of the proposed financial competitiveness model, as well as reducing possible deviations for all mining companies. This contributed to a decrease in the coefficient of variation for all mining companies under study. Thus, it can be argued that the proposed model of financial competitiveness demonstrates the best ways to introduce stochastics into work cycles in order to optimize the overall performance of a company, regardless of the country in which a company operates.

This study indicates the need to use stochastics in the management decision-making processes of an enterprise, and also confirms the effectiveness of implementing the proposed financial competitiveness model in the context of stochastic analysis for mining companies regardless of the country and region of their operation.

Based on a comprehensive analysis of the factors influencing the analysis of production activities' effectiveness and based on these factors, a rational, effective model for assessing the effectiveness of an enterprise's financial competitiveness is considered. As a result of the study, modeling and evaluation of the effectiveness of the proposed financial competitiveness model were carried out. The effectiveness of the proposed model, taking into account risks, has been substantiated.

The models developed in this study are adequate to the business environment of mining companies in the studied countries for predicting their financial competitiveness. Based on the identification of the most developed components, according to the proposed model of financial competitiveness, it seems possible to single out groups of mining companies with maximum and minimum levels of financial competitiveness. The determination of possible deviations from the predicted results confirms that the highest volumes of deviations are characteristic of leaders in terms of financial competitiveness.

The scientific contribution of this study is the formed model, the use of which in the context of the influence of its components on the integral indicator of financial competitiveness can help to minimize mining companies' risks. The study proved the feasibility of its application to increase productivity, reduce costs for managing business processes and improve the quality of investment. In general, the proposed methodology can become a significant addition to the toolkit to ensure the growth of mining companies' efficiency, regardless of their country of origin.

The limitation of this study is the assumption that financial competitiveness depends on the cost of business processes and the constancy of other factors. In the future, this study may be expanded in terms of the number of companies under study, industries, as well as countries and regions. At the same time, the range of research can be supplemented by the environmental and social components of companies' activities efficiency, by assessing the impact of mining enterprises development on the performance of a country's economy. This study can be useful for top managers and those responsible for the economic security of a business, when forming company's strategic intentions and monitoring their achievement.

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