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Economics and Society in the Era of Technological Changes and Globalization

Assessment of Level of Risk in Decision-Making in Terms of Career Exploitation

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ABSTRACT

When designing career plots the raw data are stochastic in nature. From the results of the determination of these initial data depends not only the final result of the design or evaluation, but also the feasibility of the development of the field. While there are significant errors associated with the probabilistic nature of the source data and measurement errors and errors of calculations. Risk assessment is an integral part of project documentation. The project decision-making occurs under conditions of uncertainty and risk. To minimize uncertainty, it is first necessary to identify the area of potential risk, to determine the probability of its occurrence and the potential consequences. If adverse effects cannot be excluded, a more complete understanding of the problem and contributes more mindful response to the potential risk. Analysis of the traditional approaches to designing open pits in the face of uncertainty of input data, revealed that used design methods do not account for the risk that entails the adoption and implementation of inefficient design solutions. Risk assessment is made in the design process and includes qualitative and quantitative analysis. If the evaluation of the project will be adopted for implementation, the mining companies are already faced with some problems of risk management. According to the results of the project accumulates statistics, which allows you to more accurately identify risks and work with them. When the uncertainty of the project is too high, then it can be sent back for revision, then again, there must be a risk assessment.

Keywords: Open-pit Mine, A Working Platform, Risk, Design, Reliability, Probability, Source Data
JEL Classifications: J54, M14

1. INTRODUCTION

Uncertainty information leads to uncertainty in the choice of design solution, while uncertainty determines the approach to the problem. Uncertainty can be caused by the absence or lack of information. This situation is typical for operations in which the role of uncontrollable factors plays a geological conditions. In other cases, there is uncertainty in the result organized resistance (Burenina, 2009; Geoff, 2000; Tufano, 1996).

Management of project risk - systematic processes associated with identification, risk analysis and decisions that mitigate the negative consequences of inaccurate initial geological and feasibility data, maximizing the probability of achieving the optimal parameters and indicators of the project (Burenina

The problem of the accuracy and reliability of design solutions - a characteristic feature of the present stage of development of the mining industry. In the area of improving the reliability of the design, there is a wide range of quarries outstanding issues.

Category accuracy stands as one of the objective criteria for the results of design and evaluation. Burenina (2009), Geoff (2000), Roland (2000), A Guide to the Project Management Body of Knowledge (2010), Tufano (1996), Topka (2003), U. S. Bureau of Mines (1993).

Risk analysis using the method of Monte Carlo simulation is quite a complicated procedure, with only a computer implementation. The result of this analysis is the probability distribution of possible outcomes of the project (for example, the probability of NPV<0 and the expectation of the amount of damage).

You must separate the concepts of risk and uncertainty in the mind of their non-identity. In conditions of uncertainty it is possible to start implementing the project, to postpone action, either to abandon its implementation.

Unlike uncertainty, risk arises when the decision to implement the project, i.e., the risk accepted. Decisions, and accordingly, the implementation of certain actions entail and taking appropriate risks. Therefore, the completeness and the quality of their evaluation depends on the result: Minimize losses to the successful implementation of the project as a whole (Meredith and Mantel 2012, Vellani, 2007; Grey, 1999).

Qualitative and structural changes in the economic model of our country, the requirements of the market of mineral resources, investment especially open mining, caused the complication of the requirements for the design decisions, the need for rational and optimal decisions, reducing the risk of design; raised the question of the reorganization of the design process, extensive development of feasibility studies and the improvement of design methods opencast, assessing and managing project risk.

When designing quarries the raw data are stochastic. From the results of the determination of these initial data depends not only the final result of the design or evaluation, but also the feasibility of developing the deposit. While there may be significant errors associated with both the probabilistic nature of the source data and measurement errors and errors of calculations. Risk assessment is an integral part of project documentation (Arsentie, 2002).

The project decision-making occurs under conditions of uncertainty and risk. To minimize the uncertainty in the first place it was necessary to identify the area of potential risk, determine the probability of its occurrence and the potential consequences. If the negative effects cannot be excluded, a more complete understanding of problems and promotes a more deliberate response to potential risk (Arsentie, 2002).

The analysis of traditional approaches to the design of carrier-ditch, in the conditions of uncertainty of the initial data, it was found that prima-employed design methods fail to account for the risk that entails the adoption and implementation of inefficient design decisions (Arsentie, 2002).

For reliability improvement project decision making must take into account the probabilistic nature of the source data. Consider the width of working platforms, namely dynamic design system parameters with the stochastic nature of. Probabilistic in nature due to the irregularity of conduct blasting in the quarry, aparallactus in the direction of movement of excavators in the conduct of mining operations, the organization works in career and other reasons of technological nature.

A large number of factors affecting the value of the width of the work sites, are not reliable. Width of work sites that depend on many random variables is itself a random value. According to the theory of probability random variable is such that experience, it can take a certain value, and do not know in advance what (Mustafa and Al-Bahar, 1991).

The study of the laws of distribution of the width of the work sites in open pit mines-analogues allows you to set quantitative indicators, edit them, and to ask when designing and planning of mining operations defined their values. The distribution law of a random variable called value, establishes a connection between the possible values of the random variable and their corresponding probabilities (Semenov, 2014; Qi, 2013; Zhang, 2010).

2. METHODOLOGY

The laws and parameters of the distribution width of the working platforms can be installed in statistical processing of data obtained at existing quarries-analogues, implementing steeply dipping ore deposits. The statistical processing of the material is carried out by determining the characteristics of a random variable is the empirical average of the expectation, the central moments of the distribution of normalized indices of asymmetry and kurtosis (Arsentiev, 2002; Burenina, 2009; Semenov, 2014; Camus, 2002).

Empirical average width of the working platforms

$$\bar{B} = \frac{1}{n}\sum_{i=1}^{n} B_i, \text{m} \tag{1}$$

B_i - the value of the random variable work sites ($i = 1, 2, 3 \ldots n$).

The central moment of the distribution of the random variable k-th order

$$\mu_\kappa = \frac{1}{\text{n}}\sum_{i=1}^{n} (B_i - \bar{B})^k \tag{2}$$

The second central moment is called the variance characterizes the dispersion of the random variable and is the average of the square of its deviation from the mean $\bar{B}$

$$\mu_2 = \sigma^2 = \frac{1}{\text{n}}\sum_{i=1}^{n} (B_i - \bar{B})^2 \tag{3}$$

The third central moment characterizing skewness of a distribution

$$\mu_3 = \frac{1}{\text{n}}\sum_{i=1}^{n} (B_i - \bar{B})^3 \tag{4}$$

The fourth central moment called kurtosis, characterizing peakedness distribution

$$\mu_4 = \frac{1}{\text{n}}\sum_{i=1}^{n} (B_i - \bar{B})^4 \tag{5}$$

The expectation of the random variable

$$E(B) = \frac{\sum_{i=1}^{n} B_i \cdot P_i}{\sum_{i=1}^{n} P_i} \quad (6)$$

P_i - the probability of a random variable B, (*i = 1, 2, 3.n*)

The values $\sum^2$, μ_3, μ_4 allow us to determine the normalized asymmetry index

$$\sqrt{\beta_1} = \frac{\mu_3}{\mu_2^{3/2}} \quad (7)$$

and the normalized measure of kurtosis

$$\beta_2 = \frac{\mu_4}{\mu_2^2} \quad (8)$$

The values of these characteristics are determined by the parameters of all the major distributions. To establish the law, which can be approximated distribution functions, you should use the schedule Pearson (Roland, 2000), where the applied field in the plane ([beta]$_1$, [beta]$_2$) for different distributions - normal, beta distribution, gamma distribution and log-normal.

Mathematical processing of empirical data conducted by ore quarries-analogues, has allowed to obtain the distribution of the width of the working platforms for these quarries.

For solving the problem were treated with the provisions of the mining pits-analogues. Width measurement sites were conducted on the entire working area of the quarry on the horizons of the testing. When measuring the width of the work sites received 844 values of ore and 1025 - breed.

The results of measurements of the width of the work sites by ore quarries-counterparts, implementing steeply dipping deposits, are presented in Table 1. According to the results of the measurements used to construct the histogram of the width of the work sites (Figure 1).

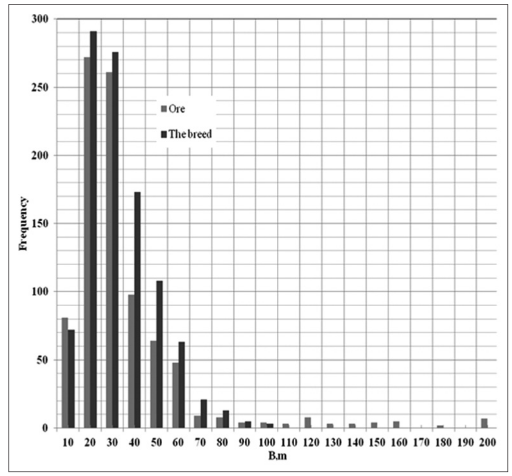
Characteristics of the random variable defined by the formulas (1-5):

Ore	$\sigma_p = 28{,}5\ M$	$\bar{B} = 31\ M$	$\mu_3 = 736381$	$\mu_4 = 12646493$
The breed	$\sigma_2 = 16{,}0\ M$	$\bar{B} = 29\ M$	$\mu_3 = 3669$	$\mu_4 = 264200$

Figure 1 sharply asymmetric distribution of the width of the work sites. Variation series with this distribution is log-normal (log-normal) distribution, where the normal distribution are subject to the values of the logarithm of the random variable. When using the logarithmically normal law are natural or decimal logarithms for all values of the random variable.

Cumulative distribution function of the width of the working platforms

Figure 1: Histograms of the distribution of the width of the working platforms ore career, earning their steeply dipping deposit



$$F(B) = \frac{1}{\sigma_{\ln} \cdot \sqrt{2\pi}} \cdot \int_0^{\ln B} \frac{1}{B} e^{-\frac{1}{2}\left(\frac{\ln B - \bar{B}_{\ln}}{\sigma_{\ln}}\right)^2} dB \quad (9)$$

(Sigma)$_{\ln}^2$ - the variance of the logarithm of the width of the working platforms;

(Sigma)$_{\ln}$ - the standard deviation (standard) empirical number;

$\bar{B}_{\ln}$ - the empirical average of the logarithms of the width of the work sites.

A lognormal distribution is characterized by the probability density, which in this case has the form

$$f(B) = \frac{1}{B \cdot \sigma_{\ln} \cdot \sqrt{2\pi}} \cdot e^{-\frac{(\ln B - \bar{B}_{\ln})^2}{2\sigma_{\ln}^2}} \quad (10)$$

The variance of the logarithm of the width of the working platforms

$$\sigma_{\ln}^2 = \frac{1}{n} \sum_{i=1}^{n} (\ln B_i - \ln B_{med})^2 m_i \quad (11)$$

n - the number of measurements equal to the sum of the frequencies of the empirical distribution;

B_{med} - the median value of the width of the work sites, m;

m_i - frequency i-th measurement interval.

The mathematical expectation of the width of the working platforms

$$E(B) = e^{\bar{B}_{\ln} + \frac{\sigma_{\ln}^2}{2}} \quad (12)$$

Figure 2 shows the curves of chastoty width working platforms ore quarries-analogues.

Normal dispersion may be determined according to the formula (49)

$$\sigma^2 = e^{2\bar{B}} \cdot (e^{2\sigma_{\ln}^2} - e^{\sigma_{\ln}^2}) \quad (13)$$

In the case when the values of the dispersions and small curves density distribution of the normal and lognormal close to each other and in the limit, when seeking the variance to zero, they are the same. Integrals and probability density function of the lognormal law not table round, so the theoretical probability density built directly by the formula (10).

The values of the logarithms of the width of the working platforms for career, earning their polymetallic deposit, are presented in Table 2. The data presented in Table 2 reflect the histogram of the logarithms of the width of the work sites (Figure 3) and the

Figure 2: The integral curves of chastoty width career working platforms

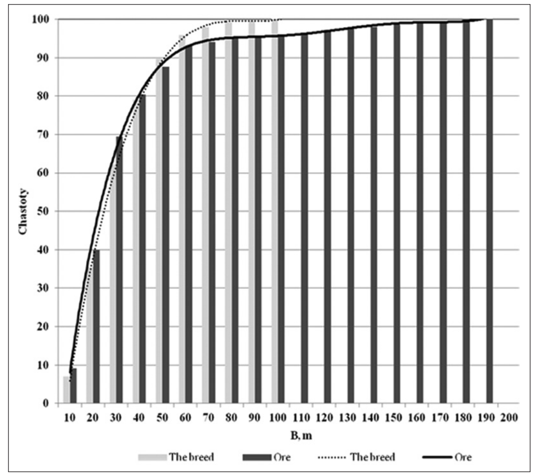


Table 1: The results of measurements of the width of the working platforms ore pit

The measurement intervals of the width of the working sites	Frequency, m_i		Cumulative frequency, M		Chastoty, m' %		Accumulated chastoty	
	Ore	The breed	Ore	The breed	Ore	The breed	Ore	The breed
0-10	81	72	81	72	9.1	7.0	9.1	7.0
11-20	272	291	353	363	30.8	28.4	39.9	35.4
21-30	261	276	614	639	29.5	26.9	69.4	62.3
31-40	98	173	712	812	11.0	16.8	80.4	79.1
41-50	64	108	776	920	7.2	10.6	87.6	89.7
51-60	48	63	824	983	5.4	6.1	93.0	95.8
61-70	9	21	833	1004	1.0	2.1	94.0	97.9
71-80	8	13	841	1017	0.9	1.3	94.9	99.2
81-90	4	5	845	1022	0.5	0.5	95.4	99.7
91-100	4	3	849	1025	0.5	0.3	95.9	100
101-110	3		852		0.4		96.3	
111-120	8		860		0.9		97.2	
121-130	3		863		0.4		97.6	
131-140	3		866		0.4		98.0	
141-150	4		870		0.5		98.5	
151-160	5		875		0.5		99.0	
161-170	-		-		-		-	
171-180	2		877		0.2		99.2	
181-190	-		-		-		-	
191-200	7		884		0.8		100	
Amount	884	1025			100	100		

Table 2: The values of the logarithms of the width of the work sites career earning polymetallic deposit

Intervals of measurement the logarithm of the width of the working platforms	Frequency, m_i		Cumulative frequency, m		Chastoty, m' %		Accumulated chastoty	
	Ore	The breed	Ore	The breed	Ore	The breed	Ore	The breed
1.61-1.9	31	29	31	29	3.6	2.8	3.6	2.8
1.91-2.2	44	36	75	65	4.9	3.5	8.5	6.3
2.21-2.5	76	81	151	146	8.6	7.9	17.1	14.2
2.51-2.8	96	98	247	244	10.9	9.6	28.0	23.8
2.81-3.1	125	139	372	383	14.1	13.6	42.1	37.4
3.11-3.4	241	256	613	639	27.2	25.0	69.3	62.4
3.41-3.7	98	173	711	812	11.2	16.9	80.5	79.3
3.71-4.0	78	124	789	936	8.8	12.1	89.3	91.4
4.01-4.3	46	72	835	1008	5.2	7.0	94.5	98.4
4.31-4.6	14	17	849	1025	1.6	1.6	96.1	100
4.61-4.9	16	-	865	-	1.8	-	97.9	-
4.91-5.2	12	-	877	-	1.3	-	99.2	-
5.21-5.5	7	-	884	-	0.8	-	100	-
Sum	884	1025						

integral curves of the particulars of the logarithms of the width of the work sites (Figure 4).

Using expressions (11-13), we determine the values of $\sigma_{\ln}^2$, $\sigma_{\ln}$, $E(B)$, $\bar{B}_{\ln}$:

Ore	$\sigma_{\ln P}^2 = 0{,}49$	$\sigma_{\ln P} = 0{,}7$	$E(B)_P = 30{,}6$	$\bar{B}_{\ln P} = 3{,}17$
The breed	$\sigma_{\ln B}^2 = 0{,}36$	$\sigma_{\ln B} = 0{,}6$	$E(B)_B = 29{,}4$	$\bar{B}_{\ln B} = 3{,}20$

Thus, the probability density function of the lognormal distribution width of the working platforms ore quarries counterparts, according to the expression (10),

$$f(B_P) = \frac{1}{0{,}7 \cdot B_P \cdot \sqrt{2\pi}} e^{-\frac{(\ln B_P - 3{,}17)}{2 \cdot 0{,}49}} \quad \text{- Ore} \qquad (14)$$

$$f(B_p) = \frac{1}{0{,}6 \cdot B_B \cdot \sqrt{2\pi}} e^{-\frac{(\ln B_p - 3{,}2)}{2 \cdot 0{,}36}} \quad \text{- the breed} \qquad (15)$$

Figure 3: Histograms of the distribution of the logarithms of the width of the working sites polymetallic career

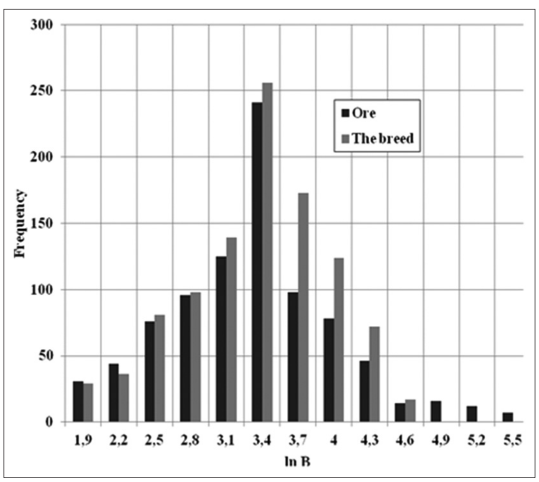
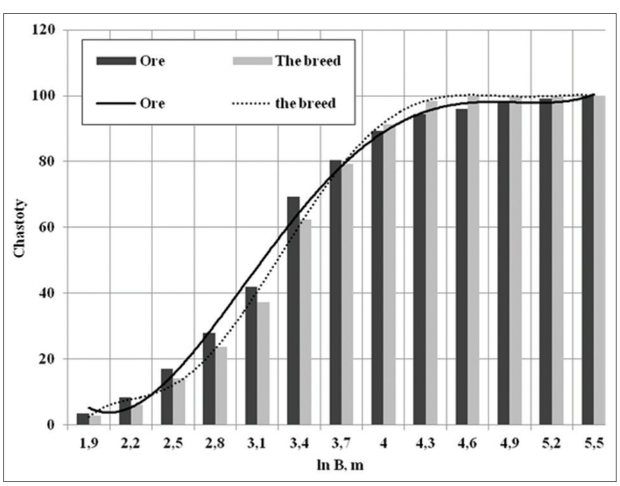


Figure 4: The integral curves of chastoty logarithms width job career sites



At a known density function probability distribution may determine the probability that a continuous random variable - width sites, will take the value corresponding to the specified interval (B_1, B_2).

This probability is defined as the definite integral of the differential of the function taken within B_1 to B_2.

$$P(B_1 < B_i < B_2) = \int_{B_1}^{B_2} f(B)dB \qquad (16)$$

Graphically the probability of a magnitude B_i the plot (B_1, B_2) is expressed by the area under the curve of probability density distribution, that is, with this plot. For this polymetallic career hit probability of the width of the working sites in the interval (B_1 = 25 m B_2 = 35 *m*).

$$P(25 < B < 35) = 0.21$$

3. RESULT

When designing quarries as the risk measure is taken the difference between the unit and the probability of occurrence of this event (Arsentiev, 2002; Meredith and Mantel 2012, "The owner's role in project risk management," 2005, Unks and Thor, 2008; Mustafa and Al-Bahar, 1991).

$$R = 1 - P(\varepsilon) \qquad (17)$$

Possible accounting of both economic and psychological consequences of risk (Camus, 2002; Kerzner, 2009). In the justification of risk should be taken into account subjective factors, as defined objective situation may present varying degrees of risk from the point of view of a specialist in different conditions. In this case, the risk is understood as the probability of economic losses associated with not acknowledge the calculated values of the width of the work sites. The probability distribution of a random variable is approximated by a lognormal law.

Degree of risk R(B) can be expressed through the probability of hitting the actual values B_i on a given area, limited left value B_{min}, and to the right value B_i, at which the total development costs ($\sum c$) matches $\sum c$ by B_{min}

$$R = 1 - P(B) = 1 - F\left(\frac{\ln B_i - \ln B_{\min}}{\sigma_{\ln}}\right) \qquad (18)$$

P(B) - the likelihood that the actual width of the work sites for a specified period of;

$(\text{sigma})_{\ln}$ - the standard deviation of the empirical range of the logarithm of the random variable;

F(B) - lognormal distribution function.

In studies (Arsentiev, 2002; Roland, 2000; Hill, 1993; Semenov 2014). the determination of the risk level of the normal distribution law. At a certain density distribution of the width of the working career sites, you can determine the level of risk of failure to achieve the set width of working platforms

$$R(B) = 1 - \frac{1}{\sigma_{\ln}\sqrt{2\pi}} \int_{\ln B_0}^{\ln B_i} \frac{1}{B_i} e^{-\frac{1}{2}\left(\frac{\ln B_0 - \ln B_i}{\sigma_{\ln}}\right)^2} dB \qquad (19)$$

$\ln B_0$ - the value of the logarithm of the width of the work sites, the corresponding $(\bar{B}_{\ln} - 3\sigma_{\ln})$.

The risk value for normal distribution of the logarithm of the width of the work sites are presented in Table 3.

A graph of the level of risk of failure to achieve the set width of the working career sites are presented in Figure 5. Analysis of the graph shows that for the conditions of ore pit in the period of development, economic risk would be 54% and 33%, respectively, when the width of the working platforms 24 m and 33.6 m

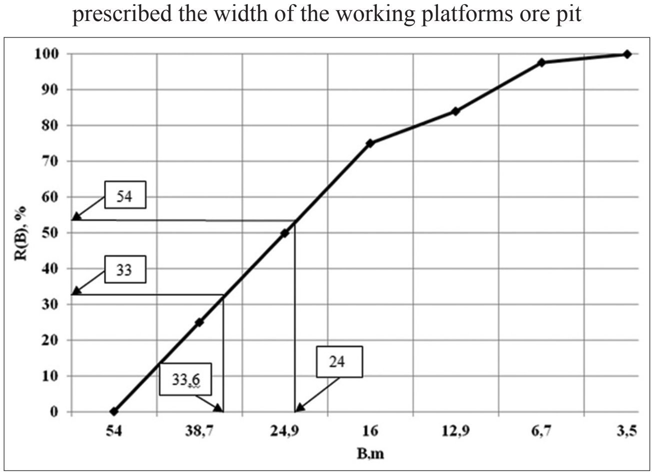
4. DISCUSSION

In paper (Hill, 1993) is considered as a variant of the deposit development assessment based on regression analysis, which involves the use of the method of least squares on the basis of: The formulation of the model view, based on the relevant theory

Table 3: The degree of risk associated with different values of the logarithms of the width of the working sites

The logarithm of the width of the working sites	$\ln B_i$	Level of risk *R(B)*, %
$\ln B_0 = \bar{B}_{\ln} - 3\sigma_{\ln}$	1.25	100
$\ln B_1 = \bar{B}_{\ln} - 2\sigma_{\ln}$	1.9	97.7
$\ln B_2 = \bar{B}_{\ln} - \sigma_{\ln}$	2.55	84.1
$\ln B_3 = \bar{B}_{\ln} - E^*$	2.76	75
$\ln B_4 = \bar{B}_{\ln}$	3.2	50
$\ln B_5 = \bar{B}_{\ln} + 2\sigma_{\ln}$	3.64	25
$\ln B_6 = \bar{B}_{\ln} + 3\sigma_{\ln}$	3.98	0

Figure 5: A graph of the level of risk of failure to achieve the prescribed the width of the working platforms ore pit



of relationships between variables; of all the factors influencing the productivity of a sign, it is necessary to identify the most significant influencing factors; steam regression sufficient if there is a dominant factor, which is used as an explanatory variable.

It is therefore necessary to know which other factors are assumed to be unchanged as in the further analysis they have to take account of the simple model and to move multiple regression; examine how a change in one trait variation changes the other.

But this method has the following disadvantages: Purposeful rejection of other factors; the impossibility of identifying. measuring certain variables (psychological factors); lack of professionalism researchers simulated; aggregation of variables (as a result of aggregation of the information is lost); incorrect determination of the structure of the model; the use of temporal information (change the time period, you can get different results regression); specification errors: Wrong choice of a mathematical function; undercount in the regression equation of a significant factor, the use of paired regression, instead of multiple); sampling error, as the researcher often has to do with sample data when establishing regular connection between the features. Sampling errors arise due to heterogeneity in the initial statistical population that is in the study of economic processes; measurement errors are the most dangerous. If the error specification can be reduced by changing the shape of the model (a kind of mathematical formulas), and sampling error - increasing the amount of raw data, the measurement error nullify all efforts to quantify the relationship between attributes.

It is of interest to identify the psychological consequences of risk. When designing quarries better to deal with reverse function - fears of the consequences of increased risk (Zhang, 2010).

Discusses four risk attitude:

- Bold attitude $\prod_c(\delta) = a(1-e^{-\delta})$; (20)
- Equality attitude $\prod_p(\delta) = a\delta$; (21)
- Cautious attitude $\prod_0(\delta) = a(e^{\delta}-1)$; (22)
- No risk $\delta = 0$ $\prod_{Hp}(\delta) = 0$; (23)

a: The ratio of proportionality, it is recommended to take a = 2.37;

δ: The relative increase compared to its minimum value (when δ = 0).

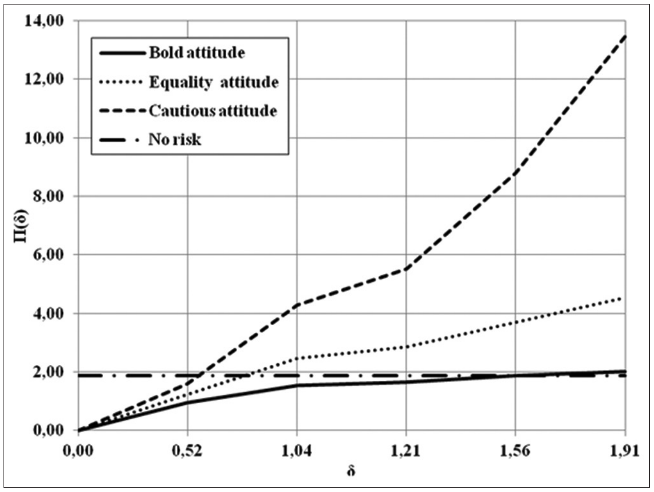
The relative increment of the logarithm of the width of the working platforms (compared to $\ln B_0 = \bar{B}_{\ln} - 3\sigma_{\ln}$)

$$\delta = \frac{\ln B_i - \ln B_0}{\ln B_0} \qquad (24)$$

Values with different levels of risk are shown in Table 4.

Figure 6 shows the function of the fears of the consequences of the relative increase of the logarithm of the width of the working platforms with different attitudes to risk.

Figure 6: Function concerns the consequences of the relative increase the logarithm of the width of the working platforms



With a bold attitude taken $\delta_c = 1.56$ (point 1. Figure 6). When the level of risk 50%. In this case the function level concerns will be $\prod_H = 1.87$. When even the attitude to risk $\delta_p = 0.88$ (point 2. Figure 6). While cautious attitude $\delta_o = 0.59$ (point 3. Figure 6).

Obtained values of the logarithms of the width of the working area at $\prod_H = 1.87$ are given in Table 5.

Determining the level of risk (Table 6) is possible using dependencies

$$\Delta = 3(1 - \frac{\delta_i}{\delta_c}) \tag{25}$$

and Table 6 for the normal distribution law.

Thus, when existing in this career, the lognormal distribution width of work sites, the optimum width of the work sites will be 24-33.6 m risk design will be 54-33%.

Consideration of the psychological aspects of the decision shows that in this case, even the orientation of the cost of the minimum width of the work sites at a rate of 24 meters increases the risk, but to work with high-risk economically feasible. To reduce the level of risk should seek to increase the value of the expectation width worksites career, reduce the probability of occurrence of widths worksites less regulatory minimum.

5. CONCLUSION

Width career working platforms should be considered as a random variable, subject to certain laws of distribution. To evaluate the probabilistic nature of the width worksites quarries developing steeply dipping ore deposits, it is advisable to use the lognormal distribution. Knowledge of the form of the distribution width career working platforms allows us to estimate the level of risk of failure in the draft adopted by the width of the work sites associated with the probabilistic nature of the source data.

Table 4: The width of the work sites at different level of risk

Exponent	Values with different levels of risk, %					
	0	20.3	15.9	25	50	75
The relative increase in, δ_i	0	0.52	10.04	10.21	10.56	10.912
The logarithm of the width of the working platforms, $\ln_B$	10.25	10.9	20.55	20.76	30.2	30.64
e^{δ}	1	1.68	2.83	3.35	4.76	6.76
Width of work sites, *B*, m	3.5	6.7	12.7	20.1	24.2	38.2

Table 5: The logarithm of the width of the work sites under different attitude to risk

Attitude to risk	ln*B*	B, m	δ_i	Level of risk *R(B)*, %
Bold	3.2	24.2	1.56	50
Smooth	2.35	10.5	0.88	9.53
Careful	1.98	7.3	0.53	3.12
No risk	1.25	3.5	0	0

Table 6: The dependence of the level of risk *R(B)* ratio of Δ for a normal distribution

Δ	*R(B)*, %	Δ	*R(B)*, %	Δ	*R(B)*, %
0.1	46.02	1.1	13.57	2.1	1.786
0.2	42.07	1.2	11.51	2.2	1.391
0.3	38.21	1.3	9.68	2.3	1.072
0.4	34.46	1.4	8.08	2.4	0.82
0.5	30.85	1.5	6.68	2.5	0.621
0.6	27.43	1.6	5.48	2.6	0.446
0.7	24.2	1.7	4.46	2.7	0.347
0.8	21.19	1.8	3.59	2.8	0.255
0.9	18.41	1.9	2.87	2.9	0.187
1.0	15.87	2.0	2.28	3.0	0.135

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