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THE DETERMINATION OF THE GEOPHYSICAL STATE OF MINING MASSIF THROUGH EXPERT ASSESSMENT

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Abstract. In this study, the use of the concordance coefficient according to Kendall's formula for expert assessment of the geophysical state of mining massif is thoroughly examined. There are various methods for expert assessments, one of which is the ranking method. In this method, experts are asked to rank quantities or factors in order of their influence, assigning ranks from most influential to least influential on a scale from 1 to n (the number of ranked factors). One drawback of this formula is the inability to consider the level of competence when conducting expert assessments. The proposed new approach involves taking into account the level of competence of experts providing recommendations regarding the influence of various factors on the geophysical state of the mining massif. Through scientific research, an analytical dependence (formula) for the concordance coefficient has been determined for the first time, considering the level of competence of experts in the field. A specific example of calculating the concordance coefficient is provided, demonstrating the significant impact of the experts' qualifications on the calculations of the concordance coefficient. The obtained data emphasize the importance of the experts' qualifications for the accuracy of concordance coefficient calculations. Such an approach allows for consideration not only of mathematical aspects but also of expert knowledge to ensure more informed decisions. The discussed analytical dependence enables comprehensive assessments by incorporating expert recommendations. The presented conclusions shed light on the practical aspect of utilizing the results for evaluating the geophysical state of mining massif. The research underscores that accounting for the qualifications of experts is a crucial element in assessing the geophysical state. The acquired data can be employed to support effective decision-making in the field of mineral extraction. Considering the level of expertise of experts enhances the reliability of information obtained during the assessment of the geophysical state. The research findings can be practically applied for a comprehensive evaluation of the geophysical state of a massif of mining rocks. In summary, the use of the concordance coefficient according to Kendall's formula, taking into account the qualifications of experts, contributes to a more accurate determination of the geophysical geophysical state of a massif of mining rocks.

Keywords: geophysical condition, expert assessment, concordance coefficient, Kendall's formula.

1. Introduction

With the deepening of open pit mines and the considerable height of waste dumps, a qualitative analysis of the geophysical condition of the slopes of waste dumps and the walls of open pit mines is more important today than ever. Assessing the geophysical state of open pit mines and dumps requires consideration not only of the results of mathematical calculations but also the competence of experts in the field. The level of expertise, knowledge of the local terrain, understanding of the overall situation in the open pit mine, intuition, and the ability to anticipate the direction of mining operations become crucial in making informed decisions regarding the assessment of the condition of waste dump areas and open pit mine walls.

The use of expert assessments allows for well-founded decisions, which is an extremely important aspect in ensuring the efficient extraction of minerals.

This approach to analyzing the geophysical condition takes into account important aspects and ensures safe and productive mining activities. Considering the qualifications of experts and the specific features of the geophysical condition of a particular massif are key factors for successful and safe open pit mining operations.

2. Methods

The method of expert assessments is a set of logical and mathematical procedures aimed at obtaining conclusions from an expert or a group of experts on a specific is-

sue. The main advantage of this method lies in the ability to use the experience and intuition of a group of competent specialists for making optimal decisions. Expert assessments can be used to establish risk characteristics, assess the importance of various variables, or make decisions. The advantages of this method include the absence of the need for expensive software and the simplicity of calculations. In the stability calculations of slope faces and quarry walls, this method is practically not applied, although it can be used to determine the weight of factors when using zoning to assess the condition of quarry walls based on stability factors.

There are several methods for conducting expert assessments, one of which is ranking, where experts are asked to rank quantities or factors in terms of their influence, assigning ranks from 1 to n (the number of ranked factors). To assess the degree of agreement among experts, the Kendall formula [1] is used, one of the drawbacks of which is the inability to account for the level of expertise when performing expert assessments.

The goal of the conducted research is to achieve the possibility of considering the qualification of experts when calculating the concordance coefficient using Kendall's formula.

The task involves the practical calculation of the concordance coefficient, taking into account the qualification of experts, and deriving an analytical dependency (formula) that considers the level of qualification (ranks) of experts in assessing their concordance.

3. Theoretical part

The article [2] describes the use of the method of expert assessments to determine the weight of factors influencing the stability of a mountain massif. The results of calculations are provided, where the concordance coefficient was determined using Kendall's formula [1], with a value of 0.479.

We take the data from the expert assessment (Table 1). Each expert is assigned a value representing their level of qualification in the considered question in the form of an expert qualification coefficient (rank) K_i for each i-th expert ($i = 1…m$). The qualification coefficient of the i-th expert should be an integer. The lower the value of the expert's qualification coefficient, the lower their qualification is considered. With a qualification coefficient equal to 1, the expert's qualification is considered the lowest.

The range of assigned qualification coefficients can vary depending on the chosen scale from 1 to ∞. In the example mentioned above, the qualification coefficient values range from 1 to 5, where 5 represents the highest expert qualification, and 1 represents the lowest.

Here are the thoughts of each expert presented as several separate opinions, coordinated with consideration of the expert's qualification rating. Using Expert A as an example, whose qualification coefficient is 4, we illustrate the creation of imaginary thoughts of additional (virtual) experts, the number of which should equal the value of his qualification coefficient.

Table 1 – Aggregated Result of Expert Assessment of Factors

Factor Influence Indicator	Volume	Impact of Drilling and Blasting	Operations Mine Impact	Hydro-geology	Presence of Weak Layer Rock	Fracture Porosity of Rocks	Expert Qualification Coefficient on a 5-point Scale (K_i, i=1…m)	Sum
Expert's name	Factor number (j , j=1…n)							
	1	2	3	4	5	6		
Expert A	1	6	5	4	3	2	4	21
Expert B	1	2	5	6	3	4	3	21
Expert C	2	5	6	4	1	3	1	21
Expert D	1	6	2	5	4	3	1	21
Expert E	3	4	2	6	1	5	1	21
Expert F	1	6	5	4	3	2	2	21
Expert G	3	5	6	2	1	4	1	21
Expert H	2	3	5	4	1	6	4	21
Expert I	2	4	5	3	1	6	4	21
Expert J	2	4	5	3	1	6	5	21

In this case, the number of imaginary thoughts of additional experts is 4, and the value of each factor's indicator equals the value set by Expert A. (Table 2).

Table 2 – Creation of an Imaginary Distribution of the Opinion of Expert A

Factor Influence Indicator		Volume	Impact of Drilling and Blasting	Operations Mine Impact	Hydro-geology	Presence of Weak Layer Rock	Fracture Porosity of Rocks	Sum
Expert's name	Addi-tional Expert Number	Factor number (i)						
		1	2	3	4	5	6	
Expert A	1	1	6	5	4	3	2	21
	2	1	6	5	4	3	2	21
	3	1	6	5	4	3	2	21
	4	1	6	5	4	3	2	21

Similarly, "virtual" opinions opinions are created for other experts and compiled into a general table, labeling them as Expert A-1, Expert A-2... Expert A- K_i ; where K_i is the number of "virtual" experts equal to their qualification.

Table 3 of virtual experts is created to facilitate the calculation of the concordance coefficient, taking into account the qualifications of the experts.

Table 3 – Distribution of Expert Opinions According to Their Qualifications

Factor Influence Indicator	Volume	Impact of Drilling and Blasting	Operations Mine Impact	Hydro-geology	Presence of Weak Layer Rock	Fracture Porosity of Rocks	Sum
Expert's name	Factor number (j, j =1 ... n)						
	1	2	3	4	5	6	
Expert A-1	1	6	5	4	3	2	21
Expert A-2	1	6	5	4	3	2	21
Expert A-3	1	6	5	4	3	2	21
Expert A-4	1	6	5	4	3	2	21
Expert B-1	1	2	5	6	3	4	21
Expert B-2	1	2	5	6	3	4	21
Expert B-3	1	2	5	6	3	4	21
Expert C-1	2	5	6	4	1	3	21
Expert D-1	1	6	2	5	4	3	21
Expert E-1	3	4	2	6	1	5	21
Expert F-1	1	6	5	4	3	2	21
Expert F-2	1	6	5	4	3	2	21
Expert G-1	3	5	6	2	1	4	21
Expert H-1	2	3	5	4	1	6	21
Expert H-2	2	3	5	4	1	6	21
Expert H-3	2	3	5	4	1	6	21
Expert H-4	2	3	5	4	1	6	21
Expert I-1	2	4	5	3	1	6	21
Expert I-2	2	4	5	3	1	6	21
Expert I-3	2	4	5	3	1	6	21
Expert I-4	2	4	5	3	1	6	21
Expert J-1	2	4	5	3	1	6	21
Expert J-2	2	4	5	3	1	6	21
Expert J-3	2	4	5	3	1	6	21
Expert J-4	2	4	5	3	1	6	21
Expert J-5	2	4	5	3	1	6	21

When performing an assessment using this method, the average value of the ranks of the set of factors S_a and the average deviation q_j of the average rank of the j-th factor from the sum of the ranks of the factor provided by all experts are determined:

$$q_j = S_a - S_j = \frac{\sum_{j=1}^{n}\sum_{i=1}^{m} R_{ij}}{n} - \sum_{i=1}^{m} R_{ij}, \quad (1)$$

where m – the number of experts assessing this factor; n – the number of factors; R_{ij} – the value of the rank given by the i-th expert to the j-th factor; S_j – the sum of the rank values R_{ij} given by all experts to the j-th factor; S_a – the average value of the ranks of a set of factors.

The value of the concordance coefficient is determined by Kendall's formula [2]:

$$W = \frac{12\sum_{j=1}^{n} q_j^2}{m^2(n^3 - n)} = 0{,}5518. \quad (2)$$

Now let's decompose the formula describing the deviation of the average rank q_j into components and replace the "imaginary opinions" with the competence coefficients of experts (K_i , i=1 ... m):

$$q_j = S_a - S_j = \frac{\sum_{j=1}^{n}\sum_{i=1}^{m} R_{ij} \cdot K_i}{n} - \sum_{i=1}^{m} R_{ij} \cdot K_i \,. \quad (3)$$

4. Results

Substituting q_i from equation (3) into the formula for calculating the sum of squares q_i, get:

$$\sum_{j=1}^{n} q_j^2 = \sum_{j=1}^{n}\left(S_a - S_j\right)^2 = \sum_{j=1}^{n}\left(\frac{\sum_{j=1}^{n}\sum_{i=1}^{m} R_{ij} \cdot K_i}{n} - \sum_{i=1}^{m} R_{ij} \cdot K_i\right)^2 = 6528. \quad (4)$$

The total number of "imaginary thoughts" is equal:

$$d = \sum_{i=1}^{m} K_i = 26. \quad (5)$$

Based on Kendall's formula, we obtain the formula for calculating the concordance coefficient, which takes into account the qualifications of each expert:

$$W = \frac{12\sum_{j=1}^{n}\left(\frac{\sum_{j}\sum_{i} R_{ij}\cdot K_{ij}}{n} - \sum_{j=1}^{m} R_{ij}\cdot K_{ij}\right)^2}{\left(\sum_{i=1}^{m} K_i\right)^2 (n^3 - n)} = 0{,}5518\,. \qquad (6)$$

Thus, if not considering the qualifications of experts, the concordance coefficient will be 0.479. Taking into account the qualifications of experts, the concordance coefficient will be 0.552, which is 15% higher.

Accounting for the qualifications of experts significantly influences the value of the concordance coefficient, and therefore, the application of a method that allows for considering the qualifications of experts more accurately solves the task of determining the concordance coefficient. That is, the application of a method that allows taking into account the qualifications of experts more accurately solves the task of determining their agreement. The number of points characterizing the qualification of an expert is influenced by competence, objectivity, propensity for independent systematic thinking, activity, etc.

5. Conclutions

1. For the first time, based on the Kendall formula, an analytical formula has been developed to determine the concordance coefficient, taking into account the qualifications of experts.

2. Incorporating the qualifications of experts into the calculation using the Kendall formula allows for a more comprehensive assessment of the concordance of opinions and provides a more realistic picture of the assessment of factors.

3. The research results can be applied in practice when conducting a comprehensive assessment of the geophysical condition of the mining rock massif.

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ВИЗНАЧЕННЯ ГЕОФІЗИЧНОГО СТАНУ МАСИВУ ГІРНИЧИХ ПОРІД ЕКСПЕРТНИМ ШЛЯХОМ

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Анотація. У цьому дослідженні детально розглядається використання коефіцієнта конкордації згідно з формулою Кендалла для експертної оцінки геофізичного стану гірничого масиву. Існують різноманітні методи проведення експертних оцінок, одним із них є метод ранжування. В рамках цього методу експертам пропонується роз-

ташувати величини чи чинники в порядку їхнього впливу, присвоюючи їм ранги від найбільш впливових до менш впливових за шкалою від 1 до n (кількість ранжованих чинників). Одним з недоліків цієї формули є неможливість врахування рівня кваліфікації експерта при проведенні експертної оцінки. Запропонований новий підход передбачає врахування рівня кваліфікації експертів, які надають рекомендації з урахуванням впливу різних факторів на геофізичний стан гірничого масиву. В ході наукового дослідження вперше була визначена аналітична залежність (формула) для коефіцієнта конкордації, яка враховує рівень компетентності експертів у даній галузі. Наведено конкретний приклад розрахунку коефіцієнта конкордації. Результати дослідження свідчать про значущий вплив рівня кваліфікації експертів на розрахунки коефіцієнта конкордації. Отримані дані підкреслюють важливість рівня кваліфікації експертів для точності розрахунків коефіцієнта конкордації. Такий підхід дозволяє враховувати не лише математичні аспекти, але й експертні знання для забезпечення більш обґрунтованих рішень. Розглянута аналітична залежність дозволяє проводити комплексні оцінки, враховуючи експертні рекомендації. Представлені висновки висвітлюють практичний аспект використання результатів для оцінки геофізичного стану гірничого масиву. Дослідження підкреслює, що облік кваліфікації експертів є ключовим елементом при здійсненні оцінки геофізичного стану. Отримані дані можуть бути використані для підтримки ефективних рішень у галузі видобутку корисних копалин. Врахування рівня кваліфікації експертів підвищує достовірність інформації, отриманої під час оцінки геофізичного стану. Результати досліджень можуть бути використані на практиці при виконанні комплексної оцінки геофізичного стану масиву гірничих порід.Узагальнюючи, використання коефіцієнта конкордації за формулою Кендалла з урахуванням кваліфікації експертів сприяє більш точному визначенню геофізичного стану гірничого масиву.

Ключові слова: геофізичний стан, експертна оцінка, коеффіцієнт конкордації, формула Кендалла.