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DETERMINATION OF THE RISK AT WORKPLACE, ASSESSMENT AND ITS RANK CALCULATION, IN MINING ACTIVITIES

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ABSTRACT

Compared to the major industries, mining industry has a high risk accident potential. Over ten thousand miners are killed every year, and this is just the official figure. It is assumed that the number of the injured might exceed one hundred thousand miners, and many of them remain disable [1,2]. The history of mining is linked to the development of society itself, while the regulations on mine safety can be traced back to the Roman times. Significant mining accidents and disasters were reported since the beginning of the year 1800 [2,3]. Several pathways to mine accidents have been identified within the 200-year experience, where the agents have been: hit, inrush, outbursts, explosion, falling, sliding, lifting, poisoning, etc., in different work places, such as stope-work, transport, drift-discharge, transport, maintenance, etc. Despite having identified the causality (agent) long time ago, the number of mining accidents are still disturbing. This paper aims to assess the risk from particular agents at a workplace, trending this way to determine the risk rank through empirical formulas, through parameter "P" as an accident occurrence parameter and relevant statistics on mining accidents.

Keywords: Agent; Assessment; Mine; Risk; Safety

1 INTRODUCTION

World consumption of minerals has increased to such an extent in modern times that more minerals were used in the 20th century than ever used throughout the previous centuries [4,5,6]. Practically, we are now a society that depends on automobiles, trains, telephones, television, computers, fertilizers, heavy machinery, industrial minerals for building construction, electricity production based on coal-fired power plants, nuclear plants. However, during all these times of mineral resources utilization, the mining industry and related activities have had extensive negative environmental impacts associated with natural disasters and human life loss. Unfortunately, the improvements to this are not satisfying to date [7].

In the mining industry more people are killed or injured than in any other industry worldwide. Over 15,000 miners are killed every year - and this is just the official number of deaths. There are most likely many more casualties.

Nevertheless, the society needs mining in order to meet their needs for mineral resources, and also mining has supported innovations, the economy and societal development [8,9]. On the other hand, facts and figures presented above related to mining disasters and accidents are disturbing. Despite the modern technologies and modern regulations on mine safety, the improvements during the mining activities have been insufficient. The legislation framework can never be fully comprehensive, and in line with certain mine specificities, the administrative reforms tend to be behind the technological progress [10,11].

The practice claims that the legislation on mining safety should be more flexible in terms of each mine's characteristics. Thus, mine safety management must ensure that all risks are identified, assessed and ranked properly to ensure long-term health and safety at the mine site [12,13,14].

However, risk determination, namely related to accidents, is a current challenge for many researchers due to the implications of many parameters and variables. Accident statistics, namely the consequences of accidents, have so far been the main parameters in the tendency for accident risk assessment and calculation. Nevertheless the accuracy of such a calculation depends directly on the mathematical equation but also on certain variables. For example, some researchers show the risks calculation (risk score) as a multiple of occurrence and the impact of an occurrence (consequence), as it is shown in the formula below:

Risk Score = Likelihood * Consequence [15] (1)

Thus, such a calculation tends to be based on statistics or general parameters of the mine or a working unit, whereas the experience shows that risk management in mines should be based on specific cases. Based on the statements above, the main objective of this paper is to calculate the risk in the mining production based on a specific workplace.

2 MATERIALS AND METHODS

As mentioned above, there are several formulas and methodologies that have been used to calculate and assess the risk at work, but most of them use similar methodologies of general data on work accidents, such as the number of total accidents in a year, and serious injuries in a year. Some also include small injuries. The empirical Formula (Severity index) [11,15] is:

S.I = (50F + S) x 105/ Man-shifts worked (2)

where

S.I = Severity index

F = Number of fatal accidents in a year

S = Number of serious injuries in a year

The above criterion is used to identify accident-prone mines**.**

Table 1 Mining accidents statistics for the "KEK" company – Kosovo, for time period 2017-2019 [16]

Fatal Accidents	Serious Injures	Small Injures
0	0	67

Considering the data on accidents in Tab.1, the calculation of Severity Index (S.I) will result in zero, which is non-sense with regard to KEK’s Mines Safety Management. On the other hand, if we try to calculate the risk using Formula 3 below, consequently from Table 3, we get the risk percentage of 11.25 (A=11.25%). While the Severity index Formula (2) does not present the proper way to calculate the risk in KEK mines, Formula 3 lacks the parameters that would increase the reliability, such as workplaces of accident occurrence, cause/agent of accidents, etc.

Therefore, considering these facts, and due to the reoccurrences of mines accidents caused by the same agents, it has encouraged us to use a methodology based on specific cases at a certain workplace. While the calculation is based on an empirical formula used for the assessment of the risk and its ranking, the categorisation of the risk potential is based on previous analyses of mines accidents at specific workplaces. We will use the parameter “P” as an accident occurrence parameter, with given nominal rates, from 0.90 to 7.90.

Nominal limits of parameter "P" are defined based on exposure time and under assumption of non-zero risk, as well as there is any risk with 100% chance. Below are given formulas:

$$A = \left(\frac{P}{E}\right) * E' \tag{3}$$

$$E' = \frac{t_2}{t_1} \tag{4}$$

$$8 \geq t_2 > 0, \;\; 8 \geq t_1 > 0 \tag{5}$$

where

A = Accident/ risk assessment

P = Accident occurrence parameter

E = Exposure within space where accident may occur

Volume 66 (2020), No. 1
p. 69–75, ISSN 1802-5420
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t_1 = the regular working hours per shift, or the nominal exposure time,

t_2 = the effective time of exposure

E’ = time exposure ratio

Table 1 below gives the relation between the index of nominal rate of accident occurrence “P” and categorization of working-risk area. The working-risk area is provided based on historical accidents’ statistics and it is the most important parameter in Formula 3 in order to estimate (rank) the risk of the working place.

Table 2 Relation between the nominal rate "P" and categorisation of accidents

A	B
Nominal rate of accident occurrence parameter “P”	Nominal rate of "P" based on previous categorisation of accidents
0.90	Small injury
1.90	One lost time injury
2.90	Many lost time injuries
3.90	One permanent disability/less chance of fatality
4.90	Significant of fatality
5.90	One dead
6.90	Several dead
7.90	Disaster

Risk rank of each nominal rate of accidents occurrence on percentage rate is calculated based on Formula 3 and Formula 4 and use of MS Excel - see Table 3.

3 RESULTS AND DISCUSSION

Table 3 Risk assessment (%) - Stan Terg mine / Kosovo, for the period 2007-2011

P	t_2	t_1(c=8)	$E^{'}=(t_2/t_1)$	E(c’=8)	A = (P/E)*E’	A (%)
0.90	8	c	1	c'	0.1125	11.25
1.90	8	c	1	c'	0.2375	23.75
2.90	8	c	1	c'	0.3625	36.25
3.90	8	c	1	c'	0.4875	48.75
4.90	8	c	1	c'	0.6125	61.25
5.90	8	c	1	c'	0.7375	73.75
6.90	8	c	1	c'	0.8625	86.25
7.90	8	c	1	c'	0.9875	98.75

$8 \geq t_2 > 0, \ \ 8 \geq t_1 > 0$

The t_1 and t_2 are considered constants, which means 8 regular working hours per shift, or the nominal exposure time is considered 8 hours, consequently E’=1.

c – Constant (nominal) of working hours, t_1(c=8)

c’ – Corresponding constant of working hours E(c’=8)

Volume 66 (2020), No. 1
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Table 4 Risk calculation based on time exposure at workplace

1	P	t_2	t_1(c=8)	E'=t_2/t_1	E(c'=8)	A=(P/E)E'	A(%)
2	0.9	8	c	1	c'	0.1125	11.25
3	1.9	6	c	0.75	c'	0.178125	17.81
4	2.9	8	c	1	c'	0.3625	36.25
5	3.9	4	c	0.5	c'	0.24375	24.38
6	4.9	8	c	1	c'	0.6125	61.25
7	5.9	2	c	0.25	c'	0.184375	18.44
8	6.9	8	c	1	c'	0.8625	86.25
9	7.9	8	c	1	c'	0.9875	98.75

Table 4, particularly rows 3, 5 and 7, shows the risk calculation based on time exposure at the workplace, and as can be seen, the risk rank is based on the time-exposure at the workplace (Formula 3, 4 and 5).

Table 5 Workplace risk calculation

A	B	B	C	D
Nominal rate of accident occurrence parameter "P"	Nominal rate of "P" based on previous categorisation of accidents	Workplace	Average of "P"	Corresponding A = (P/E)*E'
0.90	Small injury			
1.90	One lost time injury	Stope - Mining Agent of accident "hit/blow" "Stan Terg" mine	4.4	More than, 60%
2.90	Many lost time injuries			
3.90	One permanent disability/less chance of fatality			
4.90	Significant of fatality			
5.90	One dead			
6.90	Several dead			
7.90	Disaster			

The reliability of risk calculation based on Formula (3) consists of the quality of the statistics related to mining accidents, or the assessment of risk at the workplace. The types of accidents based on the consequences are listed in Table 2. However, the same calculation can be used if we setup the rate of risk by working places, as shown in Table 3.

Table 6 below gives the risk calculation for the Slovenian Mining Industry, based on the statistical data for the period of 2007-2011.

Table 6 Risk calculation based on Formula 3, for the Slovenian case [17]

A	B	B	C	D
Nominal rate of accident occurrence parameter "P"	Nominal rate of "P" based on previous categorisation of accidents	Workplace	Average of "P"	Corresponding based on Tab. 2 A = (P/E)*E'
0.90	Small injury	N.A	3.4	Less than 48%
1.90	One lost time injury			
2.90	Many lost time injuries			
3.90	One permanent disability/less chance of fatality			

4.90	Significant of fatality			
5.90	One dead			
6.90	Several dead			
7.90	Disaster			

N.A – No available data

Workplace risk calculation (work at the stope-mining), shown in Table 3, is calculated based on Formula 3, and based on statistics of the accidents at the Stan Terg mine, for the period 2007-2011 [18,19].

The same methodology is used to calculate the risk in Table 5, based on accident statistics of Slovenian mines, and as can be seen the accident risk assessment (A) of less than 48%.

Nevertheless, it should be highlighted that there is a lack of available data related to accidents, such as the sites of accidents, cause/agent of accidents etc., which decreases the reliability of such calculations. Consequently, this leads to general conclusions on risk at certain mining operations, which will have negative impacts on future accident prevention measures.

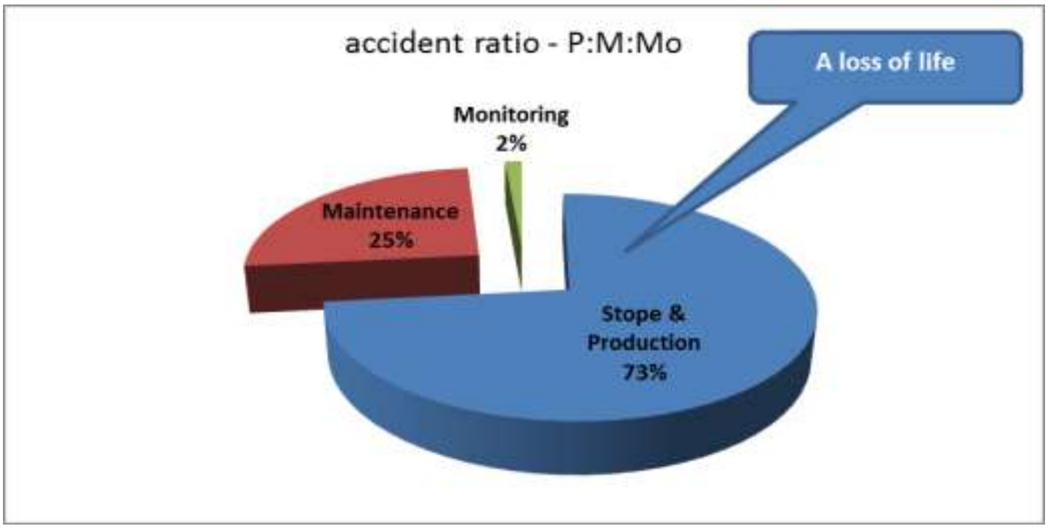

Figure 1 Ratio of accidents based on workplaces at Stan Terg mine

As shown in Table 3, the highest risk of working places at the Stan Terg mines seems to be related to stope – mining in ore extraction, and the main agent of the accidents is the "hit" – see Fig.1. Thus, the nominal rate of accident in Tab.3. column A is from 1.90 to 6.90, or on average 4.4 (Tab.3, column C). Therefore, based on Table 2, for P = 4.4, the accident risk assessment (A) is above 60 % for the workplace 'stope-mining' in the Stan Terg mine.

Volume 66 (2020), No. 1
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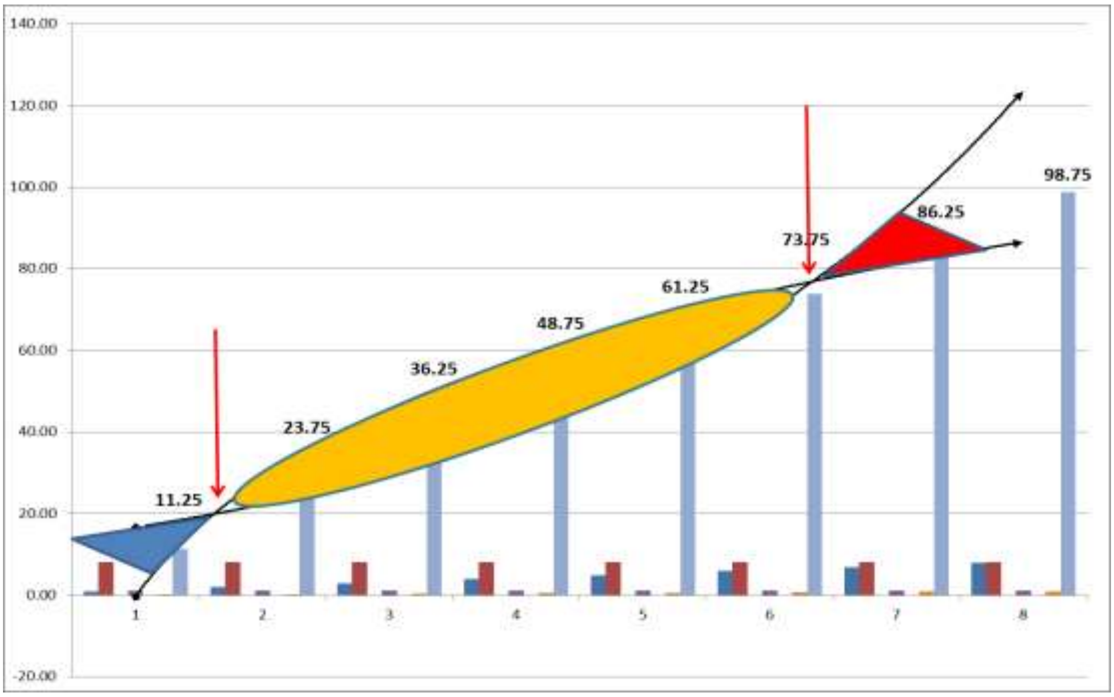

Figure 2 Risk ranking based on accident categorization

According to Table 3 and the results given in Figure 2 showing the exponential and logarithmic curves, we attempt ranking risk areas, blue as the lower risk, orange as the medium to high risk, and red describes disasters. If we refer to the risk calculation for the Stan Terg mine (A = 60%), the graph shows a high degree of risk, while based on the above analysis (Fig.1.), the most dangerous workplaces at this mine are those related to production (stope mining).

4 CONCLUSIONS

The determination and assessment of risk at the workplace, and identification of the causes of the accidents will neither eliminate all mine risks, nor will identify all probable hazards. However, these will make safety managements at different mines aware of the risks to be able to increase mining safety and increases alertness.

The main conclusion of this research is the determination of dangerous of working places, based on the parameter in Formula 3, 4 and 5 not only for calculating the risk at the workplaces, but also the reliability of the result itself. Consequently, we found that the most dangerous workplaces at Stan Terg mine are those related to production (stope mining). The findings of this research lead to recommending further specifications in the accidents reports, such as the mine name/type, exact date and time, workplace, agent-s/causes, activity at time of accident, equipment involved, management behaviour, type of injury (fatality, serious, small), individual/collective, occupation of the deceased, age, summary events and recommendations, etc. This way, we will increase the power of statistical data, and consequently we will increase the quality of risk determination and its calculation at the workplace, i.e. mine site.

This way, it will increase the quality of management safety at mines, prevent reoccurrence of mine accidents and increase the quality of accident predictions, in general. The methodology used in this paper can also be used for risk assessment in other relevant fields.

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