Mining of Mineral Deposits
Volume 18 (2024), Issue 2, 11-17

MMD JOURNAL / MINING.IN.UA

https://doi.org/10.33271/mining18.02.011

Comprehensive analysis of the mining accident forecasting and risk assessment methodologies: Case study – Stanterg Mine

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Abstract

Purpose. This research aims to outline a methodology for accident forecasting and risk assessment in mining operations using the Stanterg Mine as a case study. It emphasises the crucial role of reliable mining accident reporting and accurate data processing in forecasting accidents and effectively managing risks during mining operations.

Methods. The research paper analyzes various methodologies for forecasting mining accidents using Excel and Simple Linear Regression Method (SLRM) to analyse data selected from the Stanterg Mine accidents.

Findings. The forecast indicates that on average there are about 3 accidents per month at the Stanterg Mine. The analysis, based on a one-month study of 42 reported accidents, and assuming a steady production rate, suggests an increased risk of accidents. This is supported by a thorough assessment using a 3×3 risk assessment matrix tailored to the Stanterg Mine. Stope mining is highlighted as the most hazardous area, associated with risks ranging from moderate to extreme levels.

Originality. Mining accident analysis at the Stanterg Mine involves an examination of the incidents, including factors leading to accidents, encountered hazards and their consequences. Accident forecasting entails studying historical data, identifying patterns, and using predictive modelling to anticipate future incidents. This proactive approach enables mining companies to proactively address risks and take preventative measures, reducing the probability of accidents.

Practical implications. The systematic processing and analysis of mining accidents has revealed valuable insights into the practical application of risk assessment in mining operations. The examination of accidents at the Stanterg Mine provides researchers with crucial knowledge for effective risk assessment and management in the mining sector.

Keywords: *accident, risk, forecasting, assessment, mine*

1. Introduction

The Stanterg Mine is located 9 km northeast of the Kosovo city, Mitrovica. Mineral resources of Stanterg have been explored since 1927 and mining began in 1930. The Stanterg deposit geology comprises Palaeozoic basement rocks, Jurassic-Cretaceous sediments and Ophiolite rocks. The mineralization primarily consists of sulphide minerals, with lead-zinc-silver being the main mineralization. Additionally, approximately 70 different types of minerals accompany primary mineralization [1].

In terms of mining accidents, the mine appears to be generally safe given its geological characteristics, with low risk of major disasters and collective accidents. However, between 2007 and 2011, 292 minor injuries, 14 serious injuries and 1 fatal accident occurred at the mine. Approximately 60-70% of these incidents occurred during the production process, and 25-35% were maintenance related. Interestingly, about 2-5% of accidents occurred during monitoring or other types of work [1].

Accident forecasting of the safety state should be based on available information and observations. Accident forecasting is becoming increasingly important, both for analysing accident trends and for identifying potential hazardous sources due to frequent accidents [2]. Compared to major industries, the mining industry has a high accident risk potential. More than ten thousand miners die every year, and this is only the official data. It is estimated that the number of the injured may exceed 100 000 thousand miners, many of whom will remain disabled [3].

Therefore, any developed methodology aimed at forecasting accidents will have a significant impact on sustainable safety management in mining workplaces. This research paper analyzes various methodologies for forecasting mining accidents, with a specific focus on predicting accidents at the Stanterg Mine and their risk assessment. The study utilizes Excel and Simple Linear Regression Method (SLRM) to analyze data collected from mining site accidents. Additionally, a 3×3 risk assessment matrix for this mine is provided.

As Pothina & Ganguli concludes, in the realm of mining accident reporting, the narrative quality is of paramount importance, forming the basis in the mining risk assessment process. Accident narrative classification is an important step

Received: 5 February 2024. Accepted: 9 April 2024. Available online: 30 June 2024

Mining of Mineral Deposits. ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)

when analyzing the mining industry accidents and hence crucial for improving overall worker safety [4].

In a broader context, "risk" refers to the probability of loss, injury, or other harmful consequences resulting from hazards. The term "hazard" refers to a potential agent that may emerge and cause loss, harm and damage. "Risk assessment" encompasses a methodology for identifying hazards and assessing the consequences of their occurrence. According to the accident cause theory, if the accident risk source is effectively controlled, the major risks can be contained from the source and the accident will not occur.

To prevent the recurrence of major accidents, historical accident data can be collected for detailed analysis and characterization to find any accident risk signs [5]. The overarching research objective is to delineate a systematic framework for mining risk assessment through a rigorous examination of mining incidents at the Stanterg Mine, combined with an exhaustive review of the relevant literature on risk assessment methodologies. Risk is defined as a combination of the harm severity and the probability of this harm occurring. Risk assessment includes identifying and assessing all possible risks, mitigating them and documenting the results [6].

There are various methodologies for conducting risk assessment, such as Fuzzy Topsis, Promethee, Macbeth, Multimoora, Copras, and Todim, all based on decision-making principles. However, Gul emphasizes that the driving methodology behind the risk assessment model includes three phases: risk identification, risk assessment, as well as risk ranking and analysis [7]. On the other hand, the International Organization for Standardization (2018) emphasises three risk assessment phases, such as risk identification, risk analysis and risk assessment [8]. Drawing from this assertion, a comprehensive approach is employed to assess risks and predict mining accidents, based on the analysis of mining accidents, in particular focusing on the case study of the Stanterg Mine. The hidden dangers generated by any hazard may cause risk to spread in the system and eventually trigger accidents. Qiu Z. et al. emphasizes that to effectively prevent coal mine accidents and improve risk management and control, it is essential to study the mechanisms of causes of coal mine accidents [9].

The imperative for sustainable mining development, epitomized by risk mitigation in the mining industry, is of paramount importance, given the range of adverse ramifications inherent in this sector. These encompass not only the tragic loss of human life, but also the concomitant risks of environmental disasters and the resulting economic downturn. In this regards, the risks in the mining sector are presented in many studies. The 94 publications analyzed were published in a total of 45 journals, of which more than 70% included one paper in each [10]. Thus, in contemporary mining jurisdictions, it has become incumbent on mines to substantiate their compliance with legislative mandates concerning risk assessments. At the same time, the risk matrices are widely used by mining companies and at mine sites as part of an overall risk management approach and communication strategy [11].

It is evident from the literature review that the advancement in the study of safety risk identification has been relatively stagnant over the past decade. Despite the pressing need for enhanced safety measures, dedicated research aimed at identifying safety risk factors and employing intensive resources towards this endeavour remains notably limited. This deficiency in research efforts consequently hampers the effectiveness of risk assessment and response strategies in the mining industry [12].

In light of this critical gap, this research approach aims to facilitate more fruitful outcomes in safety risk identification in mining activities. This approach involves delving into a comprehensive examination and analysis of accident cases, extracting valuable insights and bringing to light risk factors. By analyzing accident scenarios, content analysis offers the potential to unearth previously unnoticed patterns and trends, thus enriching the understanding of safety risks in mining activities. By using software in the analysis, discussion of the results can be facilitated. The benefits of using software or models are undeniable.

Today, 21 of 57 studies report the use of software and models to analyze various causes of mining accidents, as well as to prevent and predict future accidents (e.g. SLR) [13].

Additionally, statistical analysis is integrated into this framework to further elucidate accident causes and their associated characteristics. Leveraging databases and statistical techniques via employing different methodologies, correlations, and probabilities will provide a quantitative basis for understanding risk during mining operations. This multidimensional approach not only facilitates a better understanding of safety risks, but also helps decision-makers to predict and mitigate risks during mining operations using empirical evidence.

Indeed, a comprehensive analysis based on evidence and case studies represents a concerted effort to revitalize the study of safety risk identification. By harnessing the wealth of data available from accident cases (Stanterg Mine) and employing sophisticated analytical tools, this integrated approach endeavours to assess risk and enhance safety management practices in the mining industry.

Hazard identification is a crucial phase in drawing the risk assessment path. Thus, Stemn et al. generally emphasise that the results indicate that heavy rains and groundwater remain a significant threat to the safety of surface and underground artisanal and small-scale miners. This is because rain floods have killed the most miners compared to other hazards at both underground and surface mining operations [14].

2. Materials and methods

The literature review underscores the utilization of various methodologies by different authors for risk assessment and accident forecasting. However, it is essential to recognize that the quality of accident reporting serves as a cornerstone for achieving comprehensive and sustainable risk assessment in the mining industry. Effective accident reporting not only provides crucial data for analysis, but also facilitates the identification of trends, patterns and underlying causes of accidents. By ensuring accurate and detailed reporting practices, mining companies can enhance their ability to proactively identify potential hazards, implement targeted safety measures and ultimately mitigate risks. Thus, while diverse methodologies are valuable tools for risk management, the reliability and integrity of accident reporting processes remain fundamental for fostering a culture of safety and minimizing the occurrence of workplace incidents in the mining sector. Tsoukalas et al. used Multivariable Linear Regression (MVLR) and Genetic Algorithm (GA) to study the effect of working conditions on occupational injury using occupational accident data accumulated by ship repair yards [15]. Some authors employed Fault Tree Analysis (FTA), while others have utilized Time Series Forecasting (TSF) and other pertinent methodologies.

Nevertheless, the literature review reveals a commonality among methodologies in utilizing the same algorithmic approach. This involves analysis of data on mining accidents, including accident occurrences, consequences, hazards and accident types. Notably, Huang & Zhou employed the Multimedia Big Data Methodology to forecast mining accidents. By examining diverse coal mine data, they developed an analysis model and conducted correlation analyses. The objective is to enhance the efficacy of early warning and forecasting analyses for accident risks. Consequently, the methodology aims to provide pertinent information for supervision and law enforcement, ultimately enhancing the scientific nature of these processes and bolstering their capabilities in early warning and forecasting risks of accident occurring [16].

The examined methodologies highlight that the accuracy of accident prediction, specifically in risk assessment, depends more on the processing and correlation of data than on the specific methodology employed. Utilizing fuzzy methodology for forecasting accidents, Majhi D. draws the following conclusion: the number of accidents in the mining industry is reportedly increasing, Internet of Things (IoT) can be explored for monitoring mines, but analysis and predictions can prevent accidents (Table 1). The foremost factors that increase the possibility of accidents are worker experience, age factor, shift time, and stress of worker [17].

Table 1. Fuzzy intervals of input and output variables for mining accident prediction

	Parameters	Descriptions	Fuzzy interval
Inputs	Experience	Unskilled	1 month – 1 year
		Skilled	8 years
		Professional	15
	Age	Very young	18-22 years
		Young	20-40 years
		Oldest	40-58 years
	Shift	A	6.00 AM – 2.00 PM
		B	2.00 PM – 10.00 PM
		C	10.00 PM – 6.00 AM
	Stress life	Personal life	St. < 0.9
		Mental health	0.9 < St. < 2.0
		Shift of time	St. > 2.0
Outputs	Accident prediction (AP)	Low risk	0-30%
		Possible	30-50%
		High risk	50 above

Nonetheless, the identification of risks, particularly those associated with accidents, poses a persistent challenge for numerous researchers. This complexity is due to the complex interplay of numerous factors and variables in the analysis. Accident statistics, especially the consequences of accidents, have so far played a crucial role in the efforts for accident risk assessment and calculation [18]. Hence, for certain researchers, risk assessment entails the consideration of multiple hazard occurrences and their corresponding consequences, as depicted in the following Equation (1):

$$Risk\ score = Likelihood \cdot Consequence\,. \tag{1}$$

Equation (1) illustrates risk assessment based on two primary variables, establishing that the consequence depends on the probability of hazard occurring. This underscores the critical importance of research into accident forecasting (probability) to enhance mining safety.

Despite the insights provided by Equation (1), hazard ranking and accident forecasting remain complex tasks in mining operations. Understanding, assessing and predicting the behaviour of individuals involved in a mining operation, including mining equipment and facilities, poses inherent challenges. The correlation between human factors and mining operations depends on a multitude of variables, such as worker experience, age, shift, skills and attitudes. In the study conducted by Zeqiri et al. [3], hazard ranking, that is, risk assessment, was developed using Equations (2) and (3):

$$A = \left(\frac{P}{E}\right) \cdot E'\,; \tag{2}$$

$$E' = \frac{t_2}{t_1}\,; \tag{3}$$

$$8 \ge t_2 > 0\,; \qquad 8 \ge t_1 > 0\,,$$

where:

A – accident/risk assessment;

P – accident occurrence parameter;

E – exposure in the space in which accident can occur;

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 2 shows the correlation between the potential of hazard occurrence, part "A" and consequences of hazard occurrence, part "B" of the table. This table is used as a streamline for accident forecasting and risk assessment.

Table 2. Correlation between 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

The results presented in Table 3 are computed using Equations (2) and (3), by the correlation outlined in Table 2 (column *P*). This methodology involves accident forecasting derived from the processing of mining accident data, specifically from the annual accident book. In practical terms, accident forecasting (denoted by "A") is based on the ranking of mining accidents that have occurred in the mine. These incidents are systematically assessed through data processing to provide insights into the predictive model.

3. Results and discussion

A literature review and the Injury Note-Book of the Stanterg Mine revealed that approximately 73% of mining accidents occur in the stope. A significant portion, exceeding 50%, is attributed to hit hazards, with an additional 20% stemming from slide-related accidents.

Table 3. Risk assessment based on Equations (2) and (3) and according to correlation of hazard (hazard consequences)

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

Notably, about 27% of injuries are associated with hazards the cause of which remains unidentified or unnoticed [18]. The relevant data related to mining accidents at the Stanterg Mine is shown in Table 4. As depicted in Table 4, the stope emerges as the most hazardous work environment at the Stanterg Mine, with hit-related accidents standing out as the primary hazardous agent. This finding underscores the critical importance of implementing targeted safety measures and protocols in the stope to mitigate the risk of hit-related accidents. Such measures may include enhanced training programs, strict adherence to safety protocols, implementation of protective barriers or equipment, and regular monitoring of work practices to minimize the potential for accidents.

Table 4. Relevant data related to mining accidents at the Stanterg mine

L/OCC	Stope and production	Maintenance	Monitoring	Total UG	Flotation	S	S-out	Total S	∑
Hit	81	44	2	221	16	50	5	85	306
Slide	25	9	1		13				
Weightlifting	2	3	0		0				
Poisoned/apathy	3	0	0		1				
Other	51	0	0		0				
∑	162	56	3		30				

By focusing on mitigating hit-related accidents in the stope, the Stanterg Mine can effectively prioritize the safety and well-being of its workers, ultimately fostering a safer working environment.

Figure 1 presents a comprehensive flowchart delineating the accident forecasting and risk assessment process tailored specifically for the Stanterg Mine. Created from a thorough analysis of accident data, this visual representation prioritizes incidents based on the criteria outlined in Table 2. Notably, the visualization unmistakably underscores the stope as the main point of heightened risk in the mining operations, particularly in production-related tasks. This insight underscores the imperative for targeted interventions and proactive safety measures aimed at mitigating risks inherent in stope-related activities. By leveraging this flowchart as a guiding tool, the Stanterg Mine can systematically identify, assess and address potential hazards, thereby fostering a safer work environment and minimizing the occurrence of accidents.

As depicted in Figure 2, the average monthly accident rate at the Stanterg Mine is 3.5, which corresponds to an estimated annual total of approximately 42 accidents.

Thus, based on the insights gleaned from Figure 2 and 3 visualizes the accident prediction at the Stanterg Mine. The lower confidence bound signifies a monthly decrease in the number of accidents, averaging 0.22, while the upper confidence bound suggests an increase of 5 accidents per month.

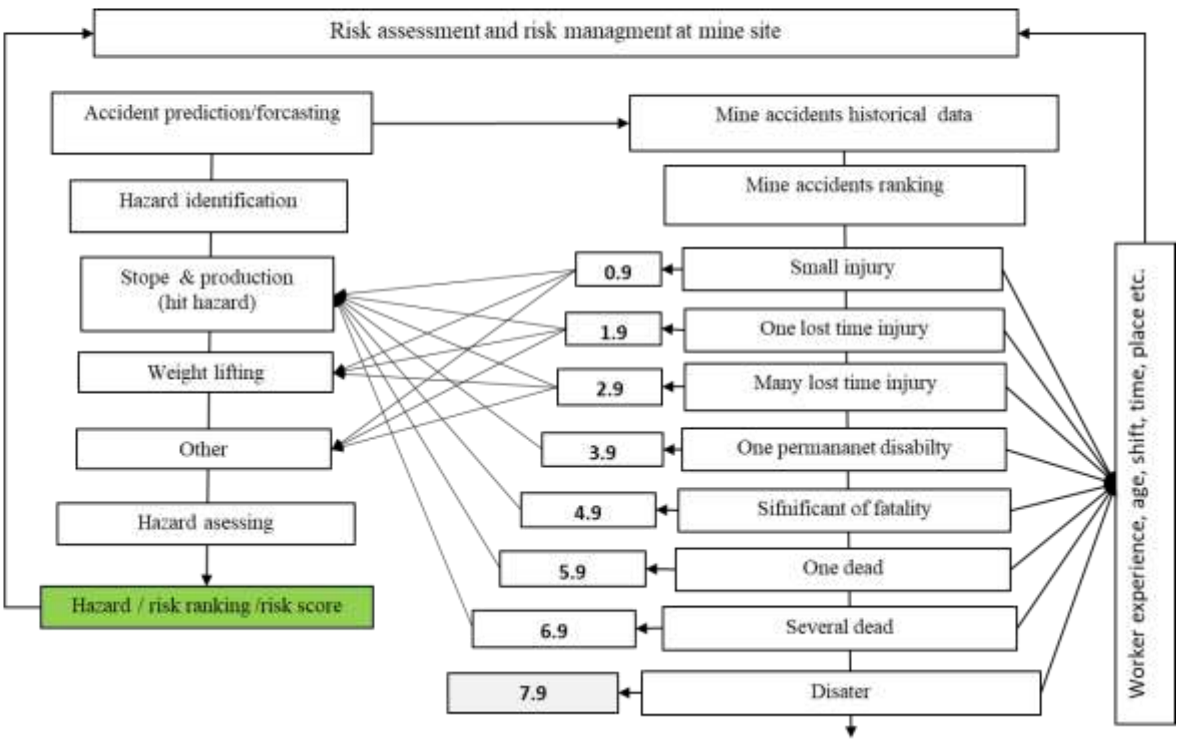

Figure 1. Flow chart of accident prediction and risk assessment for the Stanterg Mine

Figure 2. Number of the Stanterg Mine accidents per month and summary for 2007-2019

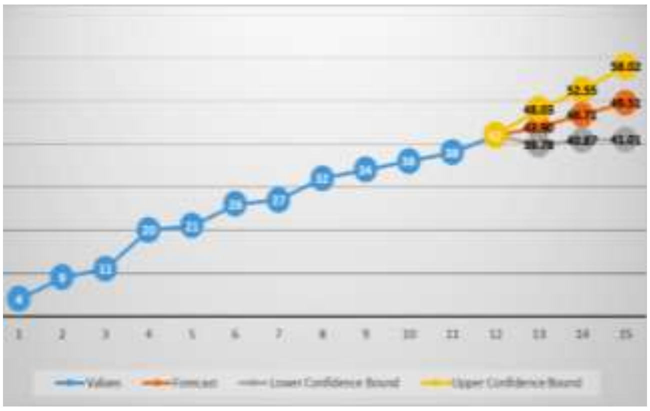

Figure 3. Forecasting of mining accidents at the Stanterg Mine

Meanwhile, the forecast indicates an average of 2 accidents per month. The graph depicts three key lines: (a) lower confidence bound illustrating a downward trend in the number of accidents, with an average monthly decrease of 0.22; (b) upper confidence bound indicating a potential upward trajectory in accidents with an average monthly increase of 5; (c) forecast line showing a stable forecast with an average of 2 accidents per month.

This visualization enables stakeholders to anticipate potential fluctuations in accident rates, facilitating proactive measures to maintain or improve mine safety standards.

However, when applying the Simple Linear Regression Method (SLRM) to the same dataset, which illustrates monthly accidents as shown in Figure 2, it yields a linear forecast indicating an average accident rate of 3.33 per month, as depicted in Figure 4.

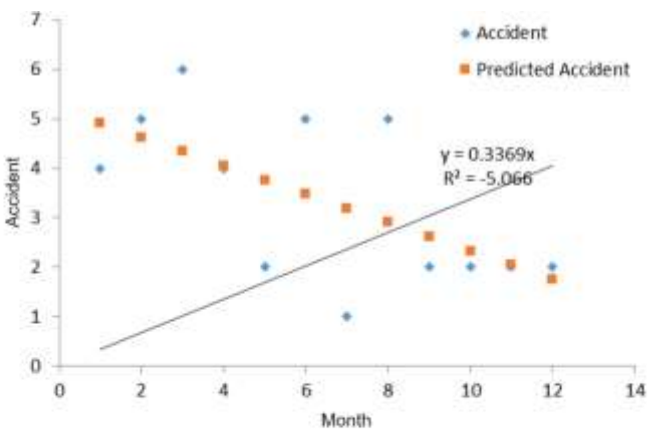

Figure 4. Line fit plot of accident forecasting for the Stanterg Mine, based on SLRM

Figure 4 showcases a linear trend line derived from the SLRM analysis, illustrating a consistent trajectory of accidents over time. With an average rate of 3.33 accidents per month, this forecast provides a straightforward representation of expected accident occurrences at the Stanterg Mine. By utilizing SLRM, mine managers can gain insights into the long-term trend of accidents, enabling them to implement targeted safety measures.

As depicted in Figure 4, the linear upward trend in the number of accidents at the Stanterg Mine is denoted by the brown milestone. This trajectory suggests a steady rise in accidents over time according to the Simple Linear Regression Method (SLRM). Conversely, the spread milestone, coloured blue, represents accident forecasts based on evidence.

Furthermore, it is worth noting that the P-value calculated from the SLRM analysis is less than the significance level (P-value < Significance F). This implies that there is a statistically significant correlation within the population, affirming the reliability of the linear forecast in capturing the underlying trend in accident occurrences.

After analyzing the results of the accident forecasting methodology outlined earlier, the risk assessment for the Stanterg Mine is encapsulated in the 3×3 matrix (Table 5). As deduced earlier and depicted in the matrix table, it is evident that the stope mining stands out as the most hazardous working area at the Stanterg Mine.

Table 5. The 3×3 risk matrix for the Stanterg Mine

Likelihood	Medium risk	Moderate risk	Extrem risk
Likely	Monitoring	Maintenance	Stope mining
Unlikely	Management	Monitoring	Maintinance
Highly Unlikely	Office work	Management	Monitoring
	Slightly harmful	Harmful	Extrem harmful
	Consequences		

As outlined in Table 5, the depiction of risk occurrence is illustrated as a bottom-up rise, whereas the consequences escalate from left to right. Notably, the most hazardous workplace at the Stanterg Mine is the stope mining area, as well as maintenance work. Conversely, monitoring tasks exhibit a lower potential for extreme risk, while managers demonstrate the least likelihood of being involved in mining accidents.

This tabular representation provides a comprehensive insight into the varying risk levels and consequences associated with the different working environments and roles at the Stanterg Mine. By discerning these patterns, stakeholders can prioritize safety measures and effectively allocate resources to mitigate risks and enhance workplace safety in all areas of mining operations.

Based on the literature review, accident forecasting methodologies primarily rely on annual accident data, specifically historical data. Therefore, the accuracy of any forecasting method depends on the consistency and reliability of the data provided, as well as the meticulous processing of accident data, encompassing factors such as time, shift, experience, workplace and hazards.

Drawing from the insights gleaned in the literature review and guided by Equations (2) and (3), as well as Table 3 and 4, along with Figures 1-3, the moderate accident forecast at the Stanterg Mine averages three accidents per month, assuming mine production as a constant variable.

In the context of risk management at the Stanterg Mine, the greatest probability of a hazardous event occurring is notably linked to stope mining operations and the various stages of production lines. Figure 1 shows that stope mining is not only related to an increased potential for hazardous accidents, but also to significant consequences associated with accidents, categorized as moderate and extreme risks (Table 1).

Sustainable risk assessment and risk management in mining operations are based on comprehensive safety management. Quality Mining Accidents Reporting (QMAR) and data processing are crucial for a reliable forecast of mining accidents. On the other hand, Zeqiri et al. assert that near-miss incident (NMI) reporting, along with its subsequent investigation and analysis holds equal significance to accident reporting and investigation in the realm of mine safety management. This emphasis on near-miss incidents contributes significantly to accident prevention in the mining industry [19]. Figure 5 illustrates the flowchart outlining the comprehensive management of evidence related to mining accidents and incidents, including near-misses. Such a systematic approach is crucial to ensure effective handling and analysis of data pertinent to safety in mining operations. By carefully processing data, mining companies can identify trends, pinpoint areas of concern, and implement preventive measures to mitigate future risks.

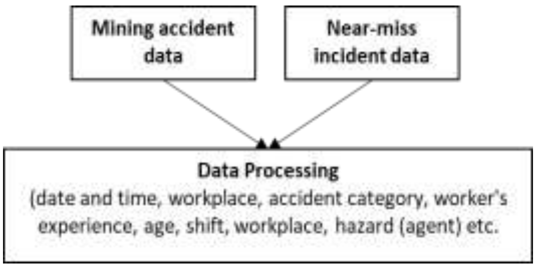

Figure 5. Qualitative mining accident reporting

Based on findings obtained in this research, it is apparent that for each formally recorded accident, there are approximately 100 near-miss incidents (NMI). This highlights the significance of integrating near-miss incidents into the reporting framework for mining accidents. Hence, a comprehensive approach to reporting mining accidents should prioritize the inclusion of near-miss incidents as a fundamental component in the process of accident prevention (Fig. 5).

This research underscores the significance of adopting a comprehensive risk assessment approach based on a robust dataset, comprising mining accidents, including near-miss incidents (NMIs), tailored specifically to certain mines such as the Stanterg Mine. By prioritizing the inclusion of near-miss incidents alongside formally recorded accidents, this approach fosters a deeper comprehension of potential hazards and vulnerabilities inherent in mining operations. Employing such a data-based methodology not only improves the accuracy of risk assessment but also facilitates the implementation of proactive measures for accident prevention and safety enhancement at the mine site, as exemplified by the Stanterg Mine.

The implementation of robust and sustainable accident reporting mechanisms in mining operations is crucial, as it serves as the basis for accurate accident forecasting and effective risk management in all mining and mining-related activities. To ensure the efficacy of these mechanisms, it is essential to integrate rigorous data processing methodologies. By employing advanced data analysis techniques such as machine learning algorithms and statistical modelling, mining companies can extract valuable insights from accident reports and historical data. This enables them to identify trends, patterns and potential risk factors, thus empowering proactive decision-making and preventive measures.

Furthermore, incorporating real-time monitoring systems and sensors into the mining environments can provide continuous data streams allowing for early detection of potential hazards and prompt intervention to mitigate risks. Additionally, fostering a culture of safety and accountability among all stakeholders, including mine workers, management, and regulatory bodies, is of paramount importance. This involves implementing comprehensive training programs, promoting open communication channels, and incentivizing adherence to safety protocols.

4. Conclusions

Regarding the Stanterg Mine incident, the analysis of forecasting bounds suggests an estimated occurrence of about three accidents per month under conditions of sustained production. However, it is imperative to recognize that these figures can vary depending on diverse operational factors and the efficacy of safety measures implemented, highlighting the need for continuous monitoring and adaptation of safety protocols.

Furthermore, the research findings emphasize that stope mining not only poses an increased risk of hazardous accidents, but also entails significant consequences, ranging from moderate to extreme risks. This underscores the critical importance of implementing robust safety protocols and preventive measures tailored specifically to address the unique challenges inherent in stope mining operations, thereby mitigating potential accidents and their associated impacts.

The comprehensive approach to hazard identification, combined with reliable evidence of mining accidents, is indispensable in the process of sustainable risk assessment and accident forecasting in mining operations and beyond them. This systematic approach forms the cornerstone of proactive risk management strategies, facilitating informed decision-making and the implementation of preventative measures to safeguard both personnel and assets.

The hazard ranking demonstrated in this research serves as the basis for risk assessment and accident prediction at the Stanterg Mine and, consequently, for mining operations in general. By prioritizing and addressing identified hazards, mining companies can proactively mitigate risks, enhance operational safety and ensure sustainable and responsible management of mining activities.

Enhancing and improving mining legislation to prioritize risk management and accident prevention is of paramount importance in ensuring the safety of workers and the environment. It is imperative to establish robust risk assessment mechanisms, incorporating comprehensive assessment of potential hazards and implementing proactive measures to mitigate them effectively. Furthermore, by including mandatory reporting systems, such as the Near Miss Incidents (NMI), is vital for identifying and addressing hazards, that is, risk assessment in mining operations and beyond them.

Author contributions

Conceptualization: ZK; Data curation: ZK, MS; Formal analysis: ZK, MS, IG; Funding acquisition: ZK, MLL; Investigation: ZK, MS; Methodology: ZK, MS; Project administration: ZK; Resources: ZK, IG; Software: ZK, MS, IG; Supervision: ZK; Validation: ZK, MS; Visualization: ZK, MS, IG, MLL; Writing – original draft: ZK, MS, MLL; Writing – review & editing: ZK, MS. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Acknowledgements

This research is funded by the University Isa Boletini Mitrovice and supported by the Stanterg mine in Trepca. Therefore, the authors would like to express their gratitude for supporting this research.

Conflicts of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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Комплексний аналіз методологій прогнозування та оцінки ризиків нещасних випадків на шахтах, тематичне дослідження – шахта Стантерг

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Мета. Розробка методології прогнозування нещасних випадків та оцінка ризиків під час гірничодобувних робіт на руднику Стантерг в якості тематичного дослідження із акцентом на вирішальній ролі надійного повідомлення про аварії на шахтах та точної обробки даних у прогнозуванні нещасних випадків та ефективному управлінні ризиками під час проведення гірничих робіт.

Методика. Проаналізовано методології прогнозування нещасних випадків у гірничодобувній промисловості з використанням програми Excel та методу простої лінійної регресії (SLRM) для аналізу даних, обраних під час нещасних випадків на шахті Стантерг.

Результати. Прогнозом встановлено, що в середньому на шахті Стантерг трапляється близько 3 нещасних випадків щомісяця. На підставі комплексного аналізу, що ґрунтується на одномісячному дослідженні 42 зареєстрованих нещасних випадків, та, враховуючи стабільний рівень виробництва, виявлено підвищений ризик нещасних випадків. Це підтверджується ретельною оцінкою із використанням матриці оцінки ризику 3×3, розробленої спеціально для шахти Стантерг. Відпрацювання очисних вибоїв виділено як найбільш небезпечну зону, пов'язану з ризиками від помірного до екстремального рівня.

Наукова новизна. Запропоновано підхід, що дозволяє гірничодобувним компаніям активно усувати ризики та вживати запобіжних заходів, знижуючи ймовірність нещасних випадків. Оригінальний підхід ґрунтується на аналіз гірничих аварій на шахті Стантерг і передбачає дослідження інцидентів, у тому числі факторів, що призводять до нещасних випадків, виявлених небезпек та їх наслідків, а також встановлення закономірностей і використання прогнозного моделювання для протидії майбутнім інцидентам.

Практична значимість. Систематична обробка та аналіз нещасних випадків на гірничих підприємствах дозволили отримати цінну інформацію щодо практичного застосування оцінки ризиків при гірничодобувних роботах. Розслідування нещасних випадків на шахті Стантерг надає дослідникам важливі знання для ефективної оцінки ризиків і управління ними у гірничодобувному секторі.

Ключові слова: *нещасний випадок, ризик, прогнозування, оцінка, шахта*

Publisher's note