Article

Management of Vulnerabilities in Ensuring the Electrical Safety of Underground Mines

Nicolae Daniel Fîță * , Dragos Pasculescu , Mila Ilieva Obretenova , Florin Gabriel Popescu , Teodora Lazar , Alin Emanuel Cruceru , Dan Cristian Lazar , Gabriela Corina Slusariuc

Posted Date: 20 February 2025

doi: 10.20944/preprints202502.1630.v1

Keywords: management; vulnerabilities; electrical safety; underground mines

Article

Management of Vulnerabilities in Ensuring the Electrical Safety of Underground Mines

Fîță Nicolae Daniel [1,*], Păsculescu Dragoș [1], Obretenova Mila Ilieva [2], Popescu Florin Gabriel [1], Lazăr Teodora [1], Cruceru Emanuel Alin [3], Lazăr Dan Cristian [1] and Slușariuc Gabriela [1]

[1] University of Petrosani, Romania; pdragos_74@yahoo.com; floringabriel82@yahoo.com; teomititica@yahoo.com; vulcaneanul@yahoo.com; ellaslusariuc@gmail.com
[2] University of Mining and Geology St. Ivan Rilski Sofia, Bulgaria; mila.ilieva@mgu.bg
[3] University Politehnica of Bucharest, Romania; alincruceru1988@gmail.com
* Correspondence: daniel.fita@yahoo.com

Abstract: Ensuring electrical safety in underground mines is a fundamental priority given to the major risks associated with this unfriendly work environment. It involves a set of technical, organisational and educational measures to reduce the hazards for workers and minimise the risks of accidents and occupational diseases due to electrical causes. The old and precarious coal extraction methods, in conjunction with the obsolete infrastructure and electrical installations, with high accidentological danger, they can endanger the lives of underground workers every day of work. The precariousness of working conditions and working materials do not accord with safety at work, overlapping with the carelessness of decision-makers, make these underground mines a major factor of accidents and professional illnesses. In this paper, the authors identified, estimated, prioritized and evaluated the vulnerabilities within underground mines and developed actions and resources necessary to mitigate, stop and/or eliminate vulnerabilities and mitigation strategy, stopping and/or eliminating them in the context of increased electrical safety.

Keywords: management; vulnerabilities; electrical safety; underground mines

---

1. Intruduction – The Situation of Underground Mines at European and National Romanian Level

Underground mines are exploitation that extract the coal in raw state, by various methods, in order to supply various industrial systems, to generate stability and economic growth. The coal is viable for its energy content and is widely used to generate electricity, but it is also used as fuel in the steel and cement industry. The coal is an important source of ensuring energy security, an element of pollution, but also a generating factor of work accidents and occupational illnesses due to the old and precarious methods of its extraction, generated by the lack of investment in mining machinery and systems and high productivity demand. For this reason underground mines have developed over time a number of vulnerabilities, which are generated by systemic dysfunctions, deficiencies or non-compliances, which represent factual states, processes and phenomena that diminish the responsiveness of infrastructures/installations to potential risks or threats or that favor their emergence and development, with consequences in terms of functionality and utility. The lack of knowledge, non-management or poor and faulty management of vulnerabilities may generate risk factors, to the objectives, values, interests and needs of infrastructures/installations, as well as to the occupational safety status. [1]

In Europe, the underground mines sector, especially coal mines, is in an accelerated process of transition, driven by the commitments to reduce greenhouse gas emissions and focus on more environmentally friendly energy sources.

The situation in Romania: [2]

- *Mine closures plans:* Romania has committed to closing the coal mines by 2030, in accordance with European commitments regarding the energy transition. Currently, there are nine lignite quarries in Oltenia and four deep bituminous coal mines in the Jiu Valley in exploitation, which are to be closed gradually;
- *Social and economic impact:* mine closures affects around 12,000 miners, most of them concentrated in the southwest of the country. Regions such as the Jiu Valley face major economic and social challenges, including high unemployment and the lack of viable economic alternatives;
- *Methane emissions:* Romania is responsible for 85% of the methane emitted by abandoned coal mines in the EU, which underlines the need for urgent measures to manage these emissions and reduce environmental impacts.

The situation in the European Union: [2]

- *Reducing coal production:* according to a special report of the European Court of Auditors, coal production in the EU has fallen significantly in recent decades as part of decarbonisation efforts;
- *Methane emissions:* underground coal mines are significant sources of methane emissions, a powerful greenhouse gas. Coal mining, particularly in underground mines, generates methane emissions which, if not reduced, continue after mine closures;
- *Transition of mining regions:* some European mining regions have managed to reinvent themselves. For example, the Ostrava region of the Czech Republic, after the closure of coal mines in the 90s, has become an IT hub, demonstrating that economic transition is possible with appropriate strategies.

Challenges and perspectives: The transition from traditional mining to renewable energy sources is a significant challenge for Romania. It is essential to implement efficient retraining strategies for former miners and to develop the infrastructure needed for new energy sources. The experiences of other European regions, such as Ostrava, can serve as models for the economic and social transformation of mining areas in Romania. [1] [2]

2. State of Art

Addressing the mining sector in ensuring the occupational safety is essential for a number of reasons, given the particularities and risks associated with this field of strategic importance for ensuring energy security. Occupational safety in mining is not only a legal obligation but also a vital component for the protection of workers' lives and health, for reducing economic costs and for the sustainability of operations. Below are some key aspects that justify this need: [3] [4]

1. High risks associated with mining:

- mining involves activities in hazardous environments, such as underground depths, unstable tunnels, exposure to toxic gases and heavy equipment usage;
- common accidents include explosions, landslides, tunnel collapse, exposure to toxic substances, or mechanical accidents;
- long-term health problems such as lung disease (e.g., silicosis) are common.

2. Strict regulations and standards:

- there are strict requirements set by national and international authorities for safety in the mining sector, these include employee training, regular equipment checks, preventive measures and emergency response;
- compliance with these standards is mandatory in order to avoid legal sanctions and to protect the reputation of companies.

3. Advanced safety technologies:

- the implementation of modern technologies, such as real-time monitoring of mine conditions, usage of robots for inspections in hazardous areas and sensors for the detection of hazardous gases, helps to reduce the risks;
- automation and robotisation of certain operations can eliminate direct exposure of workers to hazardous conditions.

4. Education and training of workers:

- it is crucial that workers are well trained in safety procedures, personal protective equipment usage and emergency management;
- regular training and simulation exercises can improve response in case of accident.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

5. Economic and social impact:

- work accidents have a significant economic impact on companies through loss of productivity, costs associated with compensation and loss of life;
- in addition, mining accidents can cause major social problems, affecting victims' families and mining-dependent communities.

6. Benefits of a proactive approach:

- reduction of the number of accidents and health problems;
- increase of the trust of workers and local communities;
- improvement of the sustainability and social responsibility of mining companies.

But the mining sector approach is also becoming a strategic, economic and environmental necessity, with important implications for the sustainable development of economies and for the efficient use of natural resources. Below are some key apects that justify this necessity: [3] [5]

1. Critical resources for economy and industry:

- the mining sector provides the raw materials needed for industries such as energy, construction, IT, and machine production;
- rare minerals and metals are essential for the development of green technologies such as batteries for electric vehicles, solar panels and wind turbines.

2. Economic impact:

- it contributes to GDP growth by generating jobs and attracting foreign investment;
- it supports local economies, especially in regions where mining is a primary activity;
- the export of mineral resources is an important source of income for many countries.

3. Strategic security:

- access to domestic mineral resources reduces import dependency and strengthens national security;
- rare minerals are of strategic importance in the geopolitical context, being used in advanced technology and defense.

4. Environmental and sustainability challenges:

- mining exploitation must be carried out responsibly in order to minimise the environmental impact;
- the need to adopt sustainable practices, such as green mining and recycling of materials, is essential in order to reduce the environmental footprint;

5. Innovation and technological development:

- modernizing the sector through advanced technologies can increase the efficiency and safety of mining processes;
- research and innovation can contribute to reducing the negative effects of mining and harnessing alternative resources.

6. Regulations and public policy:

- an integrated approach including strict policies and regulations is needed in order to ensure sustainable and equitable exploitation of resources;
- cooperation between governments, local communities and investors is crucial to ensure mutual benefits.

7. Social involvement:

- it is important that the mining sector is integrated into regional development strategies to support local communities;
- mining projects should include social responsibility initiatives to contribute to the development of infrastructure, education and health in the affected areas.

Addressing occupational safety in the mining sector is an imperative necessity, given the high risks of this field. By implementing the appropriate measures, mining can become safer, more sustainable and more economically efficient. Mining companies, governments and regulatory organisations must work together to ensure a safe and healthy working environment for all workers.

Addressing the mining sector is therefore a necessity that must take into account the balance between economic development, environmental protection and social responsibility, in order to ensure sustainable long-term benefits.

World-renowned achievements regarding the research in the field of health and safety of the underground mines and workers are listed below: [19-35]

Specialists	Entity	Paper
Wang, Q.; Cheng, T.; Lu, T.; Liu, H.; Zhang, R.; Huang, J. [6]	China University of Mining and Techology, Xuzhou, China; Hubey Polytechnic University, Huangshi, China; Guangzhou University from China; University of Wisconsin-Madison, USA.	Underground Mine Safety and Health: A Hybrid MEREC–CoCoSo System, 2024.
Imam, M.; Baina, K., Tabii, Y.; Ressami, E.M.; Adlaoui, Y.; Benzakour, I.; Abdelwahed, E.h. [7]	Mohammed V University, Rabat, Morocco; Innovation and Research, Rabat, Morocco; Meminex, Managem, Casablanca, Morocco, Cadi Ayyad University, Marrakesh, Morocco.	The future of mine safety: a comprenhensive rewiew of anti-collision sustems based on computer vision in underground mines, 2023.
Jun L.; Jianju, R.; Chen, L.; Wenbo, Z.; Fei, T. [8]	China University of Mining and Techology, Beijing, China; CCTEG Wuhan Engineering Company, Wuhan, China.	Failure mechanism and stability control of soft roof in advance support section of mining face, 2023.
Longjun, D.; Huanyu, Z.; Fang, Y.; Shuijin, B. [9]	Central South University, Changsha, China.	Risk field of rock instability using microseismic monitoringdata in deep mining, 2023.
Xingdong, Z.; Xin, Z. [10]	Northeastern University, Shenyang, China.	Design metrod and application of stope structure parameters in deep metal mines based on an improved graph, 2022.

National achievements regarding the research in the field of health and safety of the underground mines and workers are listed below:

Specialists	Entity	Paper
Vasilescu, G.; Moraru, R.; Babuț, G. [11]	INSEMEX Petrosani, Romania; University of Petrosani, Romania.	Quantitative risk assessment and safety databases in Romanian coal mining: preliminary systematic approach, 2021.
Ilias, N.; Tomescu, C.; Gaman, G.; Ghicioi, E. [12]	University of Petrosani, Romania., INSEMEX Petrosani, Romania.	Evalution of Occupational Health and Safety in romanian coal mining in terms of legislation and practice.
Arad, S.; Arad, V.; Veres, J.; Stoicuta, O. [13]	University of Petrosani, Romania	Safety excavation in salt rock used for underground storage in Romania, 2008.
Cioca, L.; Moraru, R. [14]	Lucian Blaga University from Sibiu, Romania, University of Petrosani, Romania.	Explosion and/or fire risk assessment methodology: a common approach, structured

		for underground coalmine environments, 2012.
Moraru, R.; Babut, G.; Cioca, L. [15]	University of Petrosani Romania, Lucian Blaga University from Sibiu, Romania.	Study of methane flow in caved goafs ajacent to longwall faces in Valea Jiului coal basin, 2013.

As a result of the critical analysis, 18 vulnerabilities due to dysfunctions, deficiencies and non-compliances of the mining system were identified.

Following the estimation of gravity and impact, 2 ”worst” vulnerability scenarios were generated and prioritized:

a) *precariousness of the mining security activity;*
b) *precariousness of occupational safety activity.*

The assessment of the two vulnerability scenarios resulted in the following:

a) *vulnerability level 25 – Very high (Gravity 5 x Impact 5);*

after the proposed recommendations:

b) *vulnerability level 15 – High (Gravity 5 x Impact 3).*

It can be noted that the vulnerabilities level decreased from 25 to 15 and from this context were developed the following::

a) *Necessary actions and resources to mitigate, stop and/or eliminate vulnerabilities;*
b) *Strategy to mitigate, stop and/or eliminate vulnerabilities.*

The results and utility of the study in the paper are also convergent with other specialized papers from other European countries and can serve as a model for other types of vulnerabilities assessments in the context of ensuring the occupational safety within underground mines.

The elements of novelty and originality brought into the paper are the following:

a) *Definition of dysfunctions, deficiencies and non-compliances within the mining system;*
b) *Definition of vulnerabilities and identifying them;*
c) *Estimating vulnerabilities by gravity and impact matrix;*
d) *Scenario type depending on the vulnerability level;*
e) *Prioritization of vulnerabilities;*
f) *Vulnerability assessment;*
g) *Necessary actions and resources to mitigate, stop and/or eliminate vulnerabilities;*
h) *Strategy to mitigate, stop and/or eliminate vulnerabilities.*

3. Vulnerability Management – Critical Analysis

Vulnerabilities are factual states, processes and phenomena that diminish the responsiveness of infrastructures/installations to potential risks or threats or that favor their emergence and development, with consequences in terms of functionality and utility. The lack of knowledge, non-management or poor and faulty management of vulnerabilities may generate risk factors, to the objectives, values, interests and needs of infrastructures/installations, as well as to the occupational safety status. Vulnerabilities are generated by dysfunctions, deficiencies or non-compliances of the mining system. [16]

The dysfunctions are those actions manifested by failures and/or disturbances of the functions of underground mines, with the effect of reducing, integrating or adapting of the infrastructure/installation, and the unidentification, superficial treatment or poor management of the dysfunctions automatically generates vulnerabilities, which can affect the occupational safety.

The deficiencies represent the lack of physical attributes manifested by defects or gaps and are characterized by deficit, and an infrastructure/installation within underground mines with deficiencies cannot operate at its normal parameters and urgent re-commissioning or resilience measures must be taken, for the purpose of preventing work accidents or illnesses.

The non-compliances represent the failure to meet the requirements of an infrastructure/installation within underground mines, manifested by the deviation of some characteristics from the requirements specified in the security plan or operating manual, and an

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

infrastructure/installation with non-compliances cannot operate at its normal parameters and urgent measures must be taken to eliminate non-compliances, for the purpose of preventing work accidents or illnesses.

Vulnerability management means the intrinsic approach of the following selective steps (critical analysis): [17]

a) *The identification of the vulnerabilities;*
b) *The estimation of the vulnerabilities;*
c) *The prioritization of the vulnerabilities;*
d) *The assessment of the vulnerabilities.*

3.1. The Identification of the Vulnerabilities

In *table 1* are identified the following vulnerabilities within the mining system arising from dysfunctions, deficiencies and non-compliances.

Table 1. Estimation of the identified vulnerabilities in the mining system.

No.	THE IDENTIFIED VULNERABILITY	THE GENERATING SOURCE
1.	Poor management of mining operator activity and mining installations.	Dysfunction
2.	Poor management of operative and operational management activity of underground mines.	
3.	Instability and insecurity of underground mines caused by the lack or precariousness of investments in mining infrastructure.	
4.	Precariousness of the mining security activity.	
5.	Precariousness of occupational safety activity.	
6.	Precariousness of the protection and security activity of critical mining infrastructures.	
7.	Lack of underground mine development strategies, critical infrastructure protection and mining security.	
8.	Power deficit in The National Power System.	Deficiency
9.	Deficit of high performance mining installations in underground mines.	
10.	Deficit coal storage infrastructures.	
11.	Deficit of mining financial resources.	
12.	Deficit of mining energy research and development resources.	
13.	Deficit of mining qualified and overqualified human resource.	
14.	Deficit of honest and serious human resources.	
15.	Deficit of political and legislative stability.	
16.	Precariousness and non-performance of mining equipment and appliances within underground mines.	Non-compliance
17.	Lack of coal – possible local, area, regional or national black-out, derived from the lack of coal-fired electricity.	
18.	Dependence of national systems on coal-fired electricity.	

3.2. The Estimation of the Vulnerabilities

In *table 2* are estimated by gravity and impact, the 18 vulnerabilities identified within the mining system and the type of scenario developed according to the gravity and impact matrix.

Table 2. Estimation of the identified vulnerabilities in the mining system.

No.	The identified vulnerability	Gravity estimation	Impact estimation	Vulnerability level	Scenario type

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

1.	Poor management of mining operator activity and mining installations.	4. High	4. High	16. HIGH	Plausible the worst
2.	Poor management of operative and operational management activity of underground mines.	3. Medium	3. Medium	9. MEDIUM	Moderate
3.	Instability and insecurity of The Mining System caused by the lack or precariousness of investments in mining infrastructure.	4. High	4. High	16. HIGH	Plausible the worst
4.	Precariousness of the mining security activity.	5. Very high	5. Very high	25. VERY HIGH	The worst
5.	Precariousness of occupational safety activity.	5. Very high	5. Very high	25. VERY HIGH	The worst
6.	Precariousness of the protection and security activity of critical mining infrastructures.	4. High	4. High	16. HIGH	Plausible the worst
7.	Lack of The Mining System development strategies, critical infrastructure protection and mining security of The Mining System.	3. Medium	4. High	12. MEDIUM	Moderate
8.	Power deficit in The National Power System.	3. Medium	4. High	12. MEDIUM	Moderate
9.	Deficit of high performance mining installations in The Mining System.	4. High	4. High	16. HIGH	Plausible the worst
10.	Deficit coal storage infrastructures.	2. Low	4. High	8. MEDIUM	Moderate
11.	Deficit of mining financial resources.	4. High	4. High	16. HIGH	Plausible the worst
12.	Deficit of mining energy research and development resources.	3. Medium	3. Medium	9. MEDIUM	Moderate
13.	Deficit of mining qualified and overqualified human resource.	3. Medium	3. Medium	9. MEDIUM	Moderate
14.	Deficit of honest and serious human resources.	3. Medium	3. Medium	9. MEDIUM	Moderate
15.	Deficit of political and legislative stability.	3. Medium	3. Medium	9. MEDIUM	Moderate
16.	Precariousness and non-performance of mining equipment and appliances within The Mining System.	4. High	4. High	16. HIGH	Plausible the worst
17.	Lack of coal – possible local, area, regional or national	3. Medium	4. High	12. MEDIUM	Moderate

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

	black-out, derived from the lack of coal-fired electricity.				
18.	Dependence of national systems on coal-fired electricity.	3. Medium	4. High	12. MEDIUM	Moderate
The vulnerability level is given by the product between Gravity x Impact					

GRAVITY						
	Very high 5					
	High 4					
	Medium 3					
	Low 2					
	Very low 1					
	0	**Very low 1**	**Low 2**	**Medium 3**	**High 4**	**Very high 5**
	IMPACT					
Note: The vulnerability level is given by the product between the gravity level and the impact level						

After estimating the vulnerability gravity and impact, the type of scenario will be decided:

- 1. The worst;
- 2. Plausible the worst;
- 3. Moderate.

1. The worst	**2. Plausible the worst**	**3. Moderate**

3.3. The Prioritization of the Vulnerabilities

In *table 3* are prioritized only two vulnerabilities (4 and 5) within the mining system, with the risk scenario: The worst, and gravity and impact estimation: 5 – Very high.

Table 3. Prioritization of the identified vulnerabilities in the mining system.

No.	**The identified vulnerability**	**Gravity estimation**	**Impact estimation**	**Scenario type**
4.	Precariousness of the mining security activity.	5. Very high	5. Very high	THE WORST
5.	Precariousness of occupational safety activity.	5. Very high	5. Very high	THE WORST

3.4. The Assessment of the Vulnerabilities

The assessment of the vulnerabilities consists of the following steps::

a) The pre-assessment;
b) The assessment;
c) The post- assessment.

3.4.1. The Pre-Assessment

In *table 4* are causally analyzed the identified vulnerabilities.

Table 4. The causal analysis of the identified vulnerabilities.

	The identified vulnerability	The identification of the generating source (dysfunction, deficiency, non-compliance)	The causal analysis
4.	Precariousness of the mining security activity.	Dysfunction	Lack, precariousness or non-compliance with the mining security activity within the mining system or underground or surface mining exploitation: lack, precariousness or non-compliance with mining security procedures during coal exploitation or mining closures; non-performing infrastructure, equipment, facilities and machinery during coal exploitation or mining closures.
5.	Precariousness of occupational safety activity.	Dysfunction	Lack, precariousness or non-compliance with occupational safety activity within the mining system jobs or underground or surface exploitation: lack, precariousness or non-compliance with legal occupational safety procedures and rules during coal exploitation or mining closures; lack, precariousness or non-compliance with electrical safety procedures during coal exploitation or mining closures; lack, precariousness or non-compliance with the assessment and audit from an occupational safety point of view, during coal exploitation or mining closures; lack, precariousness or non-compliance with the Prevention, Protection and Security Plan during coal exploitation or mining closures; lack, precariousness or non-compliance with legal procedures and rules on the Fire Extinguishing Plan during coal exploitation or mining closures; lack, precariousness or non-compliance with legal procedures and rules on mining rescue activity during coal exploitation or mining closures in the event of an accident or explosion.

3.4.2. The Assessment

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

The vulnerability level is calculated using the European method of risk assessment from the ISO 31000 Risk Management, adapted by the authors to the needs of underground mines in Romania (quantitative matrix on 5 levels of gravity and impact: [18]

a) *gravity – G:*
- 1: Very low;
- 2: Low;
- 3: Medium;
- 4: High;
- 5: Very high.

b) *Impact – I:*
- 1: Very low;
- 2: Low;
- 3: Medium;
- 4: High;
- 5: Very high.

Building the vulnerability level matrix:

$$NV = G \cdot I \tag{1}$$

where:

$G = [5 \quad 4 \quad 3 \quad 2 \quad 1]^T$;

$I = [1 \quad 2 \quad 3 \quad 4 \quad 5]$.

Following the calculations, it is obtained:

$$NV = \begin{bmatrix} 5 & 10 & 15 & 20 & 25 \\ 4 & 8 & 12 & 16 & 20 \\ 3 & 6 & 9 & 12 & 15 \\ 2 & 4 & 6 & 8 & 10 \\ 1 & 2 & 3 & 4 & 5 \end{bmatrix} \tag{2}$$

The classification of the vulnerability level is based on the value of the VL (vulnerability level) obtained:

- between 1 and 3: Very low (Green);
- between 4 and 6: Low (Brown);
- between 7 and 12: Medium (Yellow);
- between 13 and 16: High (Orange);
- between 17 and 25: Very high (Red).

In *table 5* is analysed the gravity level of the vulnerabilities.

Table 5. The analysis of the gravity level of the vulnerabilities.

The Gravity Analysis	Level	
The identified vulnerability: 4. Precariousness of the mining security activity. 5. Precariousness of occupational safety activity.		**1. Very low**
		2. Low
		3. Medium
		4. High
	X	**Very high**

Level		Gravity
	1. Very low	The event produces a minor disturbance in the activity, without material damage
	2. Low	The event causes minor material damage and limited disruption to activity
	3. Medium	Injuries to staff, and/or certain losses of equipment, utilities and delays in providing the service.
	4. High	Serious staff injuries, significant loss of equipment of installations and facilities, delays and/or interruption of service provision.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

X	5. Very high	The consequences are catastrophic resulting in deaths and serious injuries to staff, major losses in equipment, installations and facilities and termination of service provision.

In *table 6* is analysed the impact level of the vulnerabilities.

Table 6. The analysis of the impact level of the vulnerabilities.

The Impact Analysis	Level		
Potential deaths (persons)		1. Very low	0 – 5 people
		2. Low	6 – 10 people
		3. Medium	11 – 15 people
		4. High	16 – 20 people
	X	5. Very high	> 21 people
Potential injured persons (persons)		1. Very low	0 – 20 people
		2. Low	21 – 40 people
		3. Medium	41 – 60 people
		4. High	61 – 80 people
	X	Very high	> 81 people
Potential losses or damage to on-site infrastructures providing the main utilities: electricity, communications, drinking water, natural gas (damage)		1. Very low	temporary damage
		2. Low	considerable damage
		3. Medium	medium damage
	X	4. High	high damage
		Very high	very high damage
Potential losses or damage to the material goods of those to whom services are provided by the critical national infrastructure in question: public, commercial, private (income on invested capital)		1. Very low	0 – 10% of IIC
		2. Low	11 – 20% of IIC
		3. Medium	21 – 30% of IIC
	X	4. High	31 – 40% of IIC
		5. Very high	over 41 % of IIC
Potential losses or damage to the environment (%)		1. Very low	0 – 20%
		2. Low	21 – 40%
		3. Medium	41 – 60%
	X	4. High	61 – 80%
		Very high	over 81%
Potențiale impacturi sociale (încrederea populației) Potential social impacts (the public confidence)		1. Very low	0 – 10% of PC
		2. Low	11 – 20% of PC
		3. Medium	21 – 30% of PC
	X	4. High	31 – 40% of PC
		5.Very high	0 – 10% of PC

IIC - income on invested capital; PC - public confidence.

Level		Impact
	1. Very low	The event produces a minor disturbance in the activity, without material damage
	2. Low	The event causes minor material damage and limited disruption to activity
	3. Medium	Injuries to staff, and/or certain losses of equipment, utilities and delays in providing the service.
	4. High	Serious staff injuries, significant loss of equipment of installations and facilities, delays and/or interruption of service provision.
X	5. Very high	The consequences are catastrophic resulting in deaths and serious injuries to staff, major losses in equipment, installations and facilities and termination of service provision.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

In *table 7* are identified the involved (critical) infrastructures.

Table 7. The involved (critical) infrastructures.

The identification of the involved (critical) infrastructures	Notes
Critical energy infrastructure: power plants (through the lack of coal which is the raw material for thermo power), power substations and overhead power lines.	-

In *table 8* are analyzed the interdependencies.

Table 8. The analysis of the interdependencies.

The analysis of the interdependencies	Critical infrastructures or systems
The National Power System is interdependent with the mining system in that it provides the electricity need in case of energy insecurity, damage, crisis, power outages, or various natural disasters (earthquake, drought, frost, storms, etc.)	Critical mining and power infrastructures.

GRAVITY						
	Very high 5					The vulnerabilities 4 and 5
	High 4					
	Medium 3					
	Low 2					
	Very low 1					
	0	Very low 1	Low 2	Medium 3	High 4	Very high 5
		IMPACT				

Note: The vulnerability level is given by the product between the gravity level and the impact level

Calculated vulnerability level	
Level	**Score**
Very low	1 – 3
Low	4 – 6
Medium	7 – 12
High	13 – 16
Very high	17 – 25

In *table 9* are highlighted the proposed recommendations.

Table 9. Proposed recommendations.

The vulnerability		Proposed recommendations
4.	Precariousness of the mining security activity.	the development and application of some procedures and rules regarding the mining security, aligned and harmonised at European level, very modern and pragmatic that would ensure mining security, by the management and leaders of working parties in underground or surface mining exploitation, during coal exploitation or mining closures;

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

		massive investments from European or national funds in infrastructure, equipment, installations and high-performance machinery by mining decision makers within the Ministry of Energy and the management of underground or surface mining exploitation, during coal exploitation or mining closures.
5.	Precariousness of occupational safety activity.	the development and application of some procedures and rules regarding the occupational safety, aligned and harmonised at European level, very modern and pragmatic that would ensure the safety and security of the workers, by the management of the mining exploitation, those responsible for the occupational safety activity and leaders of working parties in underground or surface mining exploitation, during coal exploitation or mining closures; maximum strict compliance with all legal procedures and rules on the occupational safety, that would ensure the safety and security of workers, by the leaders of the working parties in underground or surface mining exploitation, during coal exploitation or mining closures; maximum strict compliance to all electrical safety procedures and rules that would ensure the safety and security of workers, by the leaders of the working parties (electrical personnel) in underground or surface mining exploitation, during coal exploitation or mining closures; the development, implementation and application of procedures and rules regarding the assessment and audit from an occupational safety point of view, aligned and harmonised at European level, very modern and pragmatic that would ensure the safety and security of workers, in order to observe the level and manner of implementation of safety and security rules by the management of underground or surface mining exploitation, during coal exploitation or mining closures; the assessment of occupational health and safety through different national or European methods, of all jobs in underground or surface mining exploitation, by the occupational health and safety risk level assessor (external or internal authorised person) and the identification of all risks that may be dangerous to the integrity or life of workers; audit of the occupational health and safety of mining exploitation on how to comply with the occupational safety activity at management level (director, chief engineer, sector head, etc.) or

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

		mining exploitation personnel (hauler, miner, gasser, brigadier, etc.); the development, implementation, application and strict compliance with all legal procedures and rules regarding the Fire Extinguishing Plan during coal exploitation or mining closures; the development, implementation, application and strict compliance with all legal procedures and rules on mining rescue activity during coal exploitation or mining closures.

In *table 10* is highlighted the vulnerability level after the proposed recommendations.

Table 10. The vulnerability level after the proposed recommendations.

Vulnerability	Identified		After the proposed recommendations	
4. Precariousness of the mining security activity. 5. Precariousness of occupational safety activity.		1. Very low		1. Very low
		2. Low		2. Low
		3. Medium	X	3. Medium
		4. High		4. High
	X	5. Very high		5. Very high

GRAVITY						
	Very high 5			The vulnerabilities 4 and 5		
	High 4					
	Medium 3					
	Low 2					
	Very low 1					
	0	Very low 1	Low 2	Medium 3	High 4	Very high 5
				IMPACT		
Note: The vulnerability level is given by the product between the gravity level and the impact level						

Calculated vulnerability level	
Level	**Score**
Very low	1 – 3
Low	4 – 6
Medium	7 – 12
High	13 – 16
Very high	17 – 25

5.3. The Post- Assessment

In *table 11* is highlighted the prioritization of the recommendations.

Table 11. The prioritization of the recommendations.

The prioritization of the recommendations	Notes

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

1. Maximum strict compliance with all legal procedures and rules on occupational safety, that would ensure the safety and security of workers, by the leaders of the working parties in underground or surface mining exploitation, during coal exploitation or mining closures; **2**. Maximum strict compliance to all electrical safety procedures and rules that would ensure the health and safety of workers, by the leaders of the working parties (electrical personnel) in underground or surface mining exploitation, during coal exploitation or mining closures; **3.** The assessment of occupational health and safety through different national or European methods, of all jobs in underground or surface mining exploitation, by the risk level assessor (external or internal authorised person) and the identification of all risks that may be dangerous to the integrity or life of workers; **4.** Audit of the occupational health and safety of mining exploitation on how to comply with the occupational health and safety activity at management level (director, chief engineer, sector head, etc.) or mining exploitation personnel (hauler, miner, gasser, brigadier, etc.); **5.** The development, implementation, application and strict compliance with all legal procedures and rules regarding the Fire Extinguishing Plan during coal exploitation or mining closures; **6.** The development and application of some procedures and rules regarding the mining security, aligned and harmonised at European level, very modern and pragmatic that would ensure mining security, by the management and leaders of working parties in underground or surface mining exploitation, during coal exploitation or mining closures; **7.** The development and application of some procedures and rules regarding the occupational safety, aligned and harmonised at European level, very modern and pragmatic that would ensure the safety and security of the workers, by the management of the mining exploitation, those responsible for the occupational health and safety activity and leaders of working parties in underground or surface mining exploitation, during coal exploitation or mining closures; **8.** The development, implementation and application of procedures and rules regarding the assessment and audit from an occupational safety point of view, aligned and harmonised at European level, very modern and pragmatic that would ensure the safety and security of workers, in order to observe the level and manner of implementation of occupational health and safety rules by the management of underground or surface mining exploitation, during coal exploitation or mining closures; **9**. The development, implementation, application and strict compliance with all legal procedures and rules on mining rescue activity during coal exploitation or mining closures; **10.** Massive investments from European or national funds in infrastructure, equipment, installations and high-performance machinery by mining decision makers within the Ministry of Energy and the management of underground or surface mining exploitation, during coal exploitation or mining closures.	-

5.4. The Development of the Strategy to Mitigate, Stop and/or Eliminate Vulnerabilities

Following the assessment of the two vulnerabilities (4 and 5), the necessary actions and resources to mitigate, stop and/or eliminate vulnerabilities (table 12) can be realised and materialized, which may generate the strategy to mitigate, stop and/or eliminate vulnerabilities (table 13).

Table 12. Necessary actions and resources to mitigate, stop and/or eliminate vulnerabilities.

Necessary actions	Necessary resources

doi:10.20944/preprints202502.1630.v1

1. Strict compliance with all procedures and legal norms regarding: Occupational Health and Safety, Electrical security, Fire Extinguishing Plan.	Control personnel
2. The assessment of the Occupational Health and Safety.	Specialized occupational health and safety personnel, internal or external (assessor/auditor)
3. The audit of the Occupational Health and Safety.	
4. The development and applcation of some legal procedures and rules on the Occupational Health and Safety and Mining Rescue.	Specialized personnel in Occupational Health and Safety and Mining Rescue
5. Massive investments from European or national funds in (critical) infrastructure, equipment, installations and high-performance mining machinery	National and European non/refundable funds

Table 13. Strategy to mitigate, stop and/or eliminate vulnerabilities.

Strategy to mitigate, stop and/or eliminate vulnerabilities (action/job)		**Importance** I Important VI Very Important U Urgent	**Execution time** S Short (1-5 years) M Medium (5-10 years) L Long (10-15 years)
1.	Maximum strict compliance with all legal procedures and rules on Occupational Health and Safety, that would ensure the health and safety of workers, by the leaders of the working parties in underground or surface mining exploitation, during coal exploitation or mining closures.	U	S
2.	Maximum strict compliance to all Electrical safety procedures and rules that would ensure the health and safety of workers, by the leaders of the working parties (electrical personnel) in underground or surface mining exploitation, during coal exploitation or mining closures.	U	S
3.	The assessment of occupational health and safety through different national or European methods, of all jobs in underground or surface mining exploitation, by the risk level assessor (external or internal authorised person)	U	S

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 February 2025 doi:10.20944/preprints202502.1630.v1

	and the identification of all risks that may be dangerous to the integrity or life of workers.		
4.	Audit of the occupational health and safety of mining exploitation on how to comply with the occupational health and safety activity at management level (director, chief engineer, sector head, etc.) or mining exploitation personnel (hauler, miner, gasser, brigadier, etc.).	U	S
5.	The development, implementation, application and strict compliance with all legal procedures and rules regarding the Fire Extinguishing Plan during coal exploitation or mining closures.	U	S
6.	The development and application of some procedures and rules regarding the mining security, aligned and harmonised at European level, very modern and pragmatic that would ensure mining security, by the management and leaders of working parties in underground or surface mining exploitation, during coal exploitation or mining closures.	U	S
7.	The development and application of some procedures and rules regarding the Occupational Health and Safety, aligned and harmonised at European level, very modern and pragmatic that would ensure the safety and security of the workers, by the management of the mining exploitation, those responsible for the occupational health and safety activity and leaders of working parties in	U	S

	underground or surface mining exploitation, during coal exploitation or mining closures.		
8.	The development, implementation and application of procedures and rules regarding the assessment and audit from an Occupational Health and Safety point of view, aligned and harmonised at European level, very modern and pragmatic that would ensure the safety and security of workers, in order to observe the level and manner of implementation of occupational health and safety rules by the management of underground or surface mining exploitation, during coal exploitation or mining closures.	U	S
9.	The development, implementation, application and strict compliance with all legal procedures and rules on mining rescue activity during coal exploitation or mining closures.	U	S
10.	Massive investments from European or national funds in infrastructure, equipment, installations and high-performance machinery by mining decision makers within the Ministry of Energy and the management of underground or surface mining exploitation, during coal exploitation or mining closures.	U	L

6. Conclusions

As a result of the critical analysis, 18 vulnerabilities were identified generated by dysfunctions, deficiencies and non-compliances of the mining system, and following the estimation of the gravity and impact, 2 ”the worst” vulnerability scenarios were generated and prioritized. The assessment of the two vulnerability scenarios resulted in actions and resources needed to eliminate the vulnerabilities, which generated the strategy to mitigate, stop and/or eliminate them. This strategy can underpin the occupational health and safety of the mining system (underground mines) and area, regional and national energy security. Through generalization and customization, this study on the mining system of Romania (underground mines) can be adapted to many European states and it highlights the possible dysfunctions, deficiencies and non-compliances generating vulnerabilities. [36] [37] The study comes in compensation with proposed measures to eliminate these vulnerabilities, materialized in a strategy to mitigate, stop and/or eliminate, which are in line with the new needs of the literature and Romanian mining spectrum. Occupational safety in underground mines is essential to protect the life and health of mining workers, and a combination of modern technology, continuous training and strict compliance with safety rules can help to significantly reduce the level of vulnerability and subsequent risk. [38] [39]

References

1. 1. Nicolae Daniel Fita, Sorina Daniela Stanila, Adriana Zamora, Occupational Health and Safety Management, LAP – Lambert Academic Publishing, ISBN: 978-620-6-73857-2, 2023.
2. 2. European Court of Auditors, *Special report 22/2022: EU support for coal regions - limited focus on socio-economic and energy transition,* 2022. https://www.eca.europa.eu/lists/ecadocuments/sr22_22/sr_coal_regions_en.pdf
3. 3. Barb Crina Maria, Fita Daniel Nicolae, *A comparative analysis of risk assessment techniques from the risk management perspective,* Proceedings of 9th International Conference on Manufacturing Science and Education – MSE 2019: Trends In New Industrial Revolution, Volume 290, DOI: 10.1051/matecconf/201929012003, WOS: 000569367700132, Sibiu, Romania, 2019.
4. 4. Sorina D. Stanila, Adriana Zamora, Daniel N. Fita, Mila Ilieva Obretenova, *Chapter 4: Experimental methods for the study of rocks dislocation within the energy mining industry from Romania,* Science and Technology - Recent Updates and Future Prospects Vol. 4, June 2024, Book Publisher International, page 43-80, ISBN 978-81-974255-8-5 (Print), ISBN 978-81-974255-6-1 (eBook), DOI: 10.9734/bpi/strufp/v4/365.
5. 5. Sorina D. Stanila, Adriana Zamora, Daniel N. Fita, Mila Ilieva Obretenova, Chapter 10: Study of apparatus and methods of research and assessment of the quality and performance of combine knives within the energy mining industry from Romania, Science and Technology - Recent Updates and Future Prospects Vol. 3, May 2024, Book Publisher International, page 122-155, ISBN 978-81-973656-4-5 (Print), ISBN 978-81-973656-7-6 (eBook), DOI: 10.9734/bpi/strufp/v3/369.
6. 6. Wang, Q.; Cheng, T.; Lu, T.; Liu, H.; Zhang, R.; Huang, J., *Underground Mine Safety and Health: A Hybrid MEREC–CoCoSo System,* Sensors 2024, 24, 1285, http://doi.org/10.3390/s24041285, 2024.
7. 7. Imam, M.; Baina, K., Tabii, Y.; Ressami, E.M.; Adlaoui, Y.; Benzakour, I.; Abdelwahed, E.h., *The future of mine safety: a comprenhensive rewiew of anti-collision sustems based on computer vision in underground mines,* Sensors 2023, 23, 4294. http://doi.org/10.3390/s23094294, 2023.
8. 8. Jun L.; Jianju, R.; Chen, L.; Wenbo, Z.; Fei, T., *Failure mechanism and stability control of soft roof in advance support section of mining face,* Minerals 2023, 13(2), 178; https://doi.org/10.3390/min13020178, 2023.
9. 9. Longjun, D.; Huanyu, Z.; Fang, Y.; Shuijin, B., *Risk field of rock instability using microseismic monitoringdata in deep mining,* Sensors 2023, 23(3), 1300; https://doi.org/10.3390/s23031300, 2023.
10. 10. Xingdong, Z.; Xin, Z., Design metrod and application of stope structure parameters in deep metal mines based on an improved graph, Minerals 2023, 13(1), 2; https://doi.org/10.3390/min13010002, 2022.
11. 11. Vasilescu, G.; Moraru, R.; Babuţ, G., *Quantitative risk assessment and safety databases in Romanian coal mining: preliminary systematic approach,* January 2022, MATEC Web of Conferences 354(6):00002, DOI: 10.1051/matecconf/202235400002, 2022.
12. 12. Ilias, N.; Tomescu, C.; Gaman, G.; Ghicioi, E., *Evalution of Occupational Health and Safety in romanian coal mining in terms of legislation and practice,* Vol. 5, Issue 9, pp.28-42 (2019), DOI: 10.37410/EMERG.2019.09.02, 2019.
13. 13. Arad, S.; Arad, V.; Veres, J.; Stoicuta, *Safety excavation in salt rock used for underground storage in Romania,* 2 June 2008, DOI: 10.22260/ISARC2008/0040008, 2008.
14. 14. Cioca, L.; Moraru, R., *Explosion and/or fire risk assessment methodology: a common approach, structured for underground coalmine environments,* October 2012, Archives of Mining Sciences 57(1):53-60, DOI: 10.2478/v10267-012-0004-7, 2012.

 doi:10.20944/preprints202502.1630.v1

15. 15. Moraru, R.; Babut, G.; Cioca, L., *Study of methane flow in caved goafs ajacent to longwall faces in Valea Jiului coal basin,* International Multidisciplinary Scientific GeoConference: SGEM, 2013.
16. 16. Adrian Mihai Șchiopu, Manuel Cristian Săvulescu, Florin Mureșan – Grecu, Gheorghe Eugen Safta, Emanuel Alin Cruceru, Nicolae Daniel Fita, *Identification, definition and propagation of systemic elements of instability and insecurity within the national mining system,* University of Petrosani – Mining Revue, ISSN-L 1220-2053 / ISSN 2247-8590, vol. 30, issue 3 / 2024, pp. 106-110, DOI: 10.2478/minrv-2024-0031, 2024.
17. 17. Gheorghe Eugen Safta, Manuel Cristian Săvulescu, Florin Mureșan – Grecu, Adrian Mihai Șchiopu, Emanuel Alin Cruceru, Nicolae Daniel Fita, *Assessment of the risk of technical incidents, disturbances and damages at Lupeni Mine,* University of Petrosani – Mining Revue, ISSN-L 1220-2053 / ISSN 2247-8590, vol. 30, issue 3 / 2024, pp. 111-117, DOI: 10.2478/minrv-2024-0032, Sciendo, 2024.
18. 18. ISO – International Organization for Standardization, *ISO 31000:2018 – Risk Management*, Geneva, Switzerland, 2024.
19. 19. Ranjan, A.; Sahu, H.B.; Misra, P. *Wireless Sensor Networks: An Emerging Solution for Underground Mines.* Int. J. Appl. Evol. Comput. (IJAEC) 2016, 7, 1–27.
20. 20. Misra, P.; Kanhere, S.; Ostry, D.; Jha, S. Safety Assurance and Rescue Communication Systems in High-Stress Environments: A Mining Case Study. IEEE Commun. Mag. 2010, 48, 66–73
21. 21. Ranjan, A.; Zhao, Y.; Sahu, H.B.; Misra, P. Opportunities and Challenges in Health Sensing for Extreme Industrial Environment: Perspectives from Underground Mines. IEEE Access 2019, 7, 139181–139195.
22. 22. National Academies of Sciences, Engineering, and Medicine. *Monitoring and Sampling Approaches to Assess Underground Coal Mine Dust Exposures;* National Academies Press: Washington, DC, USA, 2018.
23. 23. Adjiski, V.; Despodov, Z.; Mirakovski, D.; Serafimovski, D. System Architecture to Bring Smart Personal Protective Equipment Wearables and Sensors to Transform Safety at Work in the Underground Mining Industry. Rud.-Geološko-Naft. Zb. 2019, 34, 37–44.
24. 24. Jiskani, I.M.; Yasli, F.; Hosseini, S.; Rehman, A.U.; Uddin, S. Improved Z-Number Based Fuzzy Fault Tree Approach to Analyze Health and Safety Risks in Surface Mines. Resour. Policy 2022, 76, 102591.
25. 25. Poormirzaee, R.; Hosseini, S.S.; Taghizadeh, R. *Selection of Industry 4.0 Strategies to Implement Smart Mining Policy.* J. Miner. Resour. Eng. 2022.
26. 26. Poormirzaee, R.; Hosseini, S.S.; Taghizadeh, R. Choosing the Appropriate Strategy of 4.0 Industries for the Implementation of Intelligent Methods in Mining Engineering. J. Miner. Resour. Eng. 2023, 8, 71–93.
27. 27. Zhou, J.; Huang, S.; Qiu, Y. Optimization of random forest through the use of mvo, gwo and mfo in evaluating the stability of underground entry-type excavations. Tunn. Undergr. Space Technol. 2022, 124, 104494.
28. 28. Singh, S.K.; Banerjee, B.P.; Raval, S. A Review of Laser Scanning for Geological and Geotechnical Applications in Underground Mining. Int. J. Min. Sci. Technol. 2022, 33, 133–154.
29. 29. Muduli, L.; Mishra, D.P.; Jana, P.K. Application of Wireless Sensor Network for Environmental Monitoring in Underground Coal Mines: A Systematic Review. J. Netw. Comput. Appl. 2018, 106, 48–67.
30. 30. Li, M.; Liu, Y. Underground Coal Mine Monitoring with Wireless Sensor Networks. ACM Trans. Sens. Netw. 2009, 5, 10.
31. 31. Ikeda, H.; Kolade, O.; Mahboob, M.A.; Cawood, F.T.; Kawamura, Y. Communication of Sensor Data in Underground Mining Environments: An Evaluation of Wireless Signal Quality over Distance. Mining 2021, 1, 211–223.
32. 32. Theissen, M.; Kern, L.; Hartmann, T.; Clausen, E. Use-Case-Oriented Evaluation of Wireless Communication Technologies for Advanced Underground Mining Operations. Sensors 2023, 23, 3537.
33. 33. Akyildiz, I.F.; Stuntebeck, E.P. *Wireless Underground Sensor Networks: Research Challenges.* Ad Hoc Netw. 2006, 4, 669–686.
34. 34. Kumar, A.; Kingson, T.M.G.; Verma, R.P.; Kumar, A.; Mandal, R.; Dutta, S.; Chaulya, S.K.; Prasad, G.M. *Application of Gas Monitoring Sensors in Underground Coal Mines and Hazardous Areas.* Int. J. Comput. Technol. Electron. Eng. 2013, 3, 9–23.
35. 35. Osunmakinde, I.O. Towards Safety from Toxic Gases in Underground Mines Using Wireless Sensor Networks and Ambient Intelligence. Int. J. Distrib. Sens. Netw. 2013, 9, 159273.

 doi:10.20944/preprints202502.1630.v1

36. 36. Vasilescu Gabriel-Dragos, Csaszar Tiberiu-Attila, Baciu Constantin, *Research in the engineering of complex systems safety,* Environmental Engineering and Management Journal (EEMJ), June, vol.8, No.1, p.135-139, ISSN 1582-9596, WOS: 000264783000028 http://omicron.ch.tuiasi.ro/EEMJ, 2009.
37. 37. G.,D. ,Vasilescu, C., D., Petrilean, A., Kovacs, G. V., Vasilescu, D., Pasculescu, G., I., Ilcea, D.,-P., Burduhos-Nergis, C., Bejinariu, *Methodology for Assessing the Degree of Occupational Safety Specific to Hydrotechnical Construction Activities, in order to Increase Their Sustainability,* Journal: Sustainability 2021, Volume 13, Issue 3, 1105, February, WOS:000615650700001, 2021.
38. 38. Daniel Nicolae Fîță, Mila Ilieva Obretenova, Sorina Daniela Stănilă, Adriana Zamora, Safta Gheorghe Eugen, Florin Grecu–Mureșan, *Chapter 6: Assessment of Critical Infrastructures within the National Mining Subsector,* Advances and Challenges in Science and Technology, Vol. 3, 2023, Book Publisher International, ISBN (print): 978-81-19761-49-4, eBook ISBN: 978-81-19761-05-0,
39. DOI: 10.9734/bpi/acst/v3/6402B, (89 – 99), 2023.
40. 39. Nicolae Daniel Fîță, Mihai Sorin Radu, Dragoș Păsculescu, Florin Gabriel Popescu, Cristian Rada, Emilia Grigorie, Alina Daniela Handra, *Occupational Health and Safety Management – An important pillar of national security from Romania,* International Conference on Electrical, Computer and Energy Technologies - ICECET, Cape Town, South Africa, 9-10 December 2021, WOS: 000814669100358, ISBN: 978-1-6654-4231-2, DOI: 10.1109/ICECET52533.2021.9698802, Published: 2021; Indexed: 2022-07-09; Publisher: IEEE, https://ieeexplore.ieee.org/document/9698802, 2021.