GOSPODARKA SUROWCAMI MINERALNYMI – MINERAL RESOURCES MANAGEMENT

2023 Volume 39 Issue 4 Pages 49–66

DOI: 10.24425/gsm.2023.148161

HAILONG MU[1], SHANGJIU MENG[2], MIAO WANG[3], SHENGJUN ZHANG[4]

Research on a mining area risk management system based on internal control theory

Introduction

Coal is an important energy sources in the world, and China's coal production ranks first in the world. Due to China's lack of oil, less gas, and relatively rich coal, coal remains the top priority of basic energy and industrial raw materials for a long time period in the future. According to the coal economic network, China's coal production accounted for 50.5% of the global total in 2021, and coal accounted for 56% of domestic energy consumption. This shows that China plays an important role in the process of coal supply and demand, as shown in Figures 1 and 2.

✉ Corresponding Author: Shangjiu Meng; e-mail: iemmsj@163.com

[1] Key Laboratory of Earthquake Engineering and Engineering Vibration, Institute of Engineering Mechanics, China Earthquake Administration, China; Heilongjiang Province Hydraulic Research Institute, China; ORCID iD: 0000-0002-5396-9048; e-mail: 18435841543@163.com

[2] Key Laboratory of Earthquake Engineering and Engineering Vibration, Institute of Engineering Mechanics, School of Mining Engineering, Heilongjiang University of Science and Technology, China; e-mail: iemmsj@163.com

[3] Heilongjiang Province Hydraulic Research Institute, China; e-mail: Jyllwm1990@126.com

[4] Infrastructure Branch of the Third Construction Engineering Company LTD of China Construction Second Engineering Bureau, China; e-mail: shengjun812@163.com

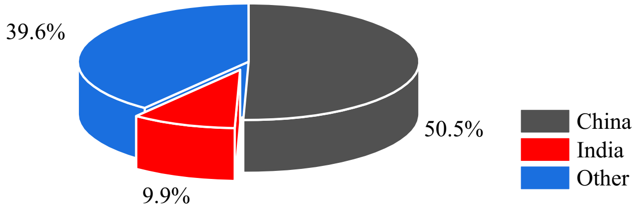

Fig. 1. Global coal production share in 2021
Source: own study

Rys. 1. Udział w globalnej produkcji węgla w 2021 roku

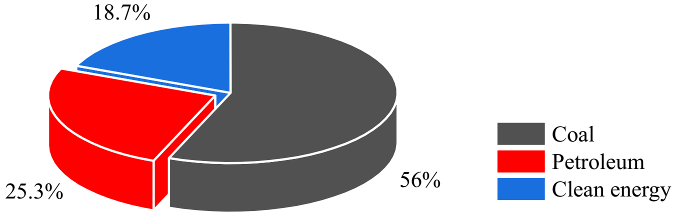

Fig. 2. The proportion of energy consumption in China in 2021
Source: own study

Rys. 2. Udział zużycia energii w Chinach w 2021 roku

The Chinese Academy of Engineering predicts that the proportion of coal in primary energy consumption will remain at about 50% before 2050. Before this, the coal-dominated energy structure would be difficult to change (Yuan 2017; Yuan et al. 2018).

At present, there are 840 high gas mines, 719 coal and gas outburst mines and 138 rock burst mines in China. In 2022, there were 168 coal mine accidents and 245 deaths in China (https://www.chinamine-safety.gov.cn/). Coal mine safety issues still face enormous challenges. Most of the cases in Table 1 are disaster accidents caused by poor management. Therefore, the safe mining of coal will always be a hot issue of concern. With the help of internal control theory, this paper makes an in-depth analysis of mining area management, and finally forms a risk management system that aims to provide new ideas and methods for mining area risk management, to reduce or eliminate risk disasters and property losses.

1. Mining area disasters and research status

About 70% of the mines in China are high-gas mines, and the risk coefficient is generally high. With the intensification of coal mining, China has entered the deep mining environment of ‘three high and one disturbance’, and the coal and rock conditions have become extremely complex. It is easy to induce coal-rock dynamic disasters under the action of mining disturbance, resulting in serious damage to roadways and casualties, and even damage to surface construction equipment and buildings in mining areas and areas surrounding mining sites (Sui et al. 2019; Xie et al. 2012). The two major mine disasters in China's history were the Benxi Lake mine disaster in 1942 and the Datong mine disaster in Shanxi in 1960. The two cases caused more than 2200 deaths, and the data was shocking and thought-provoking (Xu 2022). In recent years, China's mining disasters have also occurred frequently, accompanied by casualties. On such is example is that on February 22, 2023, a large-scale collapse occurred in the open-pit coal mine of the Xinjing Coal Industry Co., Ltd. in Alxa Left Banner, Alxa League, Inner Mongolia. The accident caused two deaths, and six injuries and contact was lost with fifty-three people. Qitaihe Lushan Coal Mine had a coal mine accident on October 7, 2021, causing serious consequences of three deaths and four injuries. On June 9, 2019, a 2.3-magnitude mine earthquake occurred in Longjiapu Mining Industry, Jilin Province, nine people were killed and ten people were injured (Zhang et al. 2005; Xu et al. 2020). On June 5, 2019, a roofing accident occurred in Pubai Nanqiao Coal Industry, Shanxi Province, resulting in the death of five miners. A gas explosion accident occurred in the Hualong Coal Industry of Yan'an City on December 24, 2018, resulting in the death of five miners (the direct cause of the accident was that the workers did not check and discharge gas in advance before entering the blind roadway, and the illegal items brought in with them ignited the gas in the roadway, resulting in gas explosion). On December 25, 2015, a 4.0 mine earthquake occurred in Pingyi, Shandong Province, causing one death and thirteen missing people (Zhao 2020). It has aroused great concern in the state, society and researchers. The mining area is affected by its complex geological environment, and the mine disaster cases show the characteristics of 'small earthquake and large disaster' (Meng et al. 2020; Meng et al. 2022). In recent years, China's million-ton mortality rate has declined, as shown in Figure 3. However, there is still a certain mortality rate. For as long as coal mining activities have been performed, coal mine safety problems have existed.

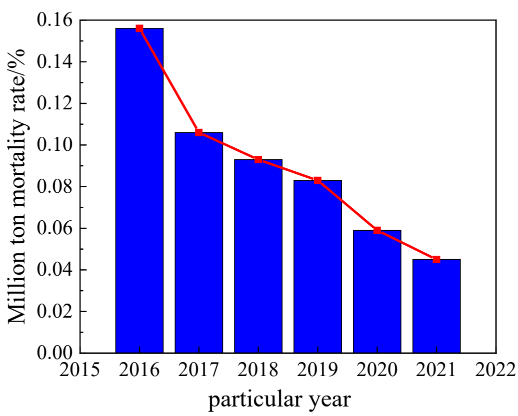

Fig. 3. Million tons mortality rate of coal mines in China in recent years
Source: own study

Rys. 3. Wskaźnik śmiertelności w kopalniach węgla w Chinach
w ostatnich latach na milion ton wydobytego węgla

Table 1. Accident cases and causes

Tabela 1. Przypadki i przyczyny wypadków

No.	Date	Case	Main causes
1	2023.02.22	A large-scale collapse accident in the open-pit coal mine of Inner Mongolia Xinjing Coal Industry Co., Ltd	Inadequate identification of factors causing the disaster , lack of risk control in job operations, single risk monitoring methods
2	2022.03.22	Roof accident in Huafeng Coal Mine, Shandong Province	Command operations in the violation of regulations, inadequate on-site safety management and supervision, inadequate employee education and training
3	2022.08.04	An increased suffocation accident in Xinfeng Coal Mine, Henan Province	Illegal operations, chaotic safety management, inadequate safety training
4	2021.05.11	A mechanical and electrical accident in Chifeng Jusen Coal Mine	Inadequate equipment safety inspections, inadequate safety education, inadequate safety management and supervision inspections
5	2021.10.07	A rockburst accident in Lushan Coal Mine, Heilongjiang Province	Illegal withdrawal of equipment, failure to conduct risk identification, chaotic on-site management
6	2021.10.11	A rockburst accident in Hujiahe Coal Mine, Shaanxi Province	Illegal organization of production, inadequate risk assessment and control
7	2021.03.25	A major coal and gas outburst accident in Shanxi Shigang Coal Industry	Adventure organization operation, inadequate risk management measures, lax safety responsibility management
8	2021.04.09	A major coal and gas outburst accident in Dongfeng Coal Mine, Guizhou	Intentionally concealing major hidden dangers, inadequate identification of risk hazards, chaotic safety technology management
9	2021.11.10	A major roof accident in the Monkey Field coal mine in Guizhou	Illegal command of operations, inadequate safety management, non-compliant safety training
10	2020.12.04	A major fire accident in the Diaoshuidong coal mine in Chongqing	Illegal withdrawal operations, lax qualification review, chaotic safety management
11	2020.02.22	A large rock burst accident in Shandong Xinjulong Energy Co., Ltd.	Insufficient risk analysis and judgment, insufficient bearing capacity of support and anchor cables, lax safety management system, poor effectiveness of safety education and training
12	2020.08.20	A large coal dust explosion accident in Liangbaosi Coal Mine, Shandong Province.	Delayed equipment dismantling, inadequate dust management, lax safety risk control, inadequate technical management

No.	Date	Case	Main causes
13	2019.09.28	The ‘9·28’ large gas explosion accident in No.3 Coal Mine of Xinjiang Saier Energy Co., Ltd., Xukuang Group	Illegal and irregular production, chaotic safety management, inadequate local safety supervision, inadequate disaster management
14	2019.07.31	Guizhou Xinxin Southwest Mining Dashu Coal Mine ‘7·31’ larger gas explosion accident	Sparks generated due to wire and cable equipment damage, irregular production organization, disorderly safety production management
15	2013.06.02	The “6.2” major gas explosion accident in Simachong Coal Mine, Shaodong County, Shaoyang City, Hunan Province	Illegal organization of production, incomplete ventilation system, inadequate safety supervision, inadequate safety education and training
16	2017.02.27	The “2.27” major explosion accident in Dahebian Coal Mine of Guizhou Shuicheng Mining	Explosion in the inner cavity of the conveyor motor, inadequate investigation and management of hidden dangers, substandard safety technical management personnel, inadequate production management
17	2019.11.18	Shanxi Fengyan Coal and Coke Group Ermugou Coal Industry “11 · 18” major gas explosion accident	Illegal mining of coal pillars, incomplete sensor deployment, unauthorized personnel carrying out blasting operations, non-standard management of personnel and initiating explosive devices
18	2015.11.28	Major gas (combustion) accident in Fuyuan Coal Mine, Jidong County on November 28th	Inadequate management of mechanical and electrical equipment and ventilation system
19	2017.01.29	The “1.29” gas suffocation accident in Shanxing Coal Industry, Xi’an District, Liaoyuan City	Failure to implement safety management system and inadequate safety education
20	2019.06.05	A roof accident at Shaanxi Pubai Nanqiao Coal Industry Co., Ltd	Inadequate identification of safety hazards and inadequate supervision of safety management
21	2016.01.21	Gas overrun alarm in Hegang Xinxing Mine and Junde Mine	An ML3.8 magnitude mine earthquake in Xing ‘an Mine of Hegang
22	2014.11.26	Gas explosion and coal dust combustion accident in Hengda Coal Industry	An ML 1.6 magnitude mine earthquake between Wulong Coal Mine and Evergrande Coal Industry Company
23	2018.05.06	An accident in a coal mine in the city of Yaschenbe-Zdreuil, Poland	A 3.4 magnitude earthquake in southern Poland

Source: own supplementing based on Zhao 2022.

The reason, in addition, to force majeure factors, is mostly attributed to 'management not being in place', coal mine safety is far from enough, and we must take scientific and effective measures to prevent it. In addition to the mining disturbance caused by mine earthquakes, other causes of serious disasters include rock bursts, coal and gas outbursts, water inrush and gas explosions (Yang et al. 2015; Zhang et al. 2022). According to statistics, it has been found that most coal mine disasters are now caused by a lack of systematic risk prevention and control, such as the illegal operation of coal miners, a lack of risk control, insufficient depth of post-operation, poor system management, incomplete investigation of hidden disaster-causing factors, inadequate research, judgment of major risks, single risk monitoring means, etc., without forming a scientific and comprehensive risk management system, which exposes the problems existing in the risk management of coal enterprises. Therefore, we should strengthen the risk management research of coal enterprises, propose key methods and technologies to prevent risk, and realize the prevention and control of risks and the containment of disasters. Applying the relevant research results to the management practice of coal enterprises is of great significance with regard to comprehensively improving the management level of mining areas and scientifically and effectively preventing risks.

Coal safety, green mining, and safety management have entered a new period of development. In the face of a new round of scientific and technological innovation and industrial transformation, the coal industry must achieve cross-border integration with the Internet, big data, and artificial intelligence, take the road of intelligent, safe, and accurate mining, and strive to achieve safe, intelligent and accurate coal mining by 2050 (Li et al. 2020; Yuan 2021).

The industrial safety axiom proposed by Heinrich (Heinrich 1931) systematically expounds on the relationship between people and things, and the relationship between accident prevention and management measures. This axiom can be well applied to the field of mine safety (Yuan et al. 2020). Based on multi-factor indexes, Li et al. (Li et al. 2009), You et al. (You et al. 2011) and Liu et al. (Liu et al. 2013) formed a coal mine safety risk integrated management system with multi-factor evaluation indexes. Wang et al. (Wang et al. 2014) constructed the coal mine safety index system from aspects of the environment, emergency, personnel, mechanical equipment and enterprise management. Hao et al. (Hao et al. 2015) constructed a green and efficient evaluation index system for mine work safety. He et al. (He et al. 2016) added safety supervision management, historical indicators and timeliness indicators, and established a new indicator system to predict possible future accidents. Some scholars have also studied dynamic risk monitoring and early warning and realized the internal control security risk pre-control system (Qiao 2013; Yang et al. 2015). However, most of the existing research is based on the analytic hierarchy process, fuzzy comprehensive evaluation method, and correlation method to study the risks of commercial finance and safety management of enterprises, while there are relatively few studies on the risk of safety management in mining areas based on internal control theory.

In order to scientifically and effectively manage the mining area, this paper introduces the internal control theory, analyzes the five elements of internal control, and then provides the basis for the construction of the risk management system in the mining area. Based on the internal control theory, referring to the existing coal mine safety risk assessment system, the coal mine safety risk management framework is finally constructed to provide theoretical and technical support for coal mine safety and effective mining in the new era.

2. Internal control and risk management

The purpose of internal control activities is to ensure the reliability of financial statements, effective operation and compliance with laws and regulations. Since the COSO Committee of the United States put forward the concept, objectives and five elements of internal control in 1992, this concept has been widely used. After different stages of development, risk-oriented internal control has been formed, and this process of change has continuously highlighted the important role of 'risk management'. Although the internal control theory is mostly applied to enterprise management, its perfect management ideas can be used for reference by mine-safety management. With the continuous development and progress of the social economy, as the core five elements of internal control, it has different manifestations in the whole operation of mining area management. Furthermore, in high-risk areas of the mining area, the human environment, and natural environment may become potential risks, so risk management of the mining area is particularly important.

2.1. Internal control elements

1) Control the environment

The quality of the control environment directly affects whether mining area management can be performedsmoothly, which lays the foundation of management efficiency. The control environment involves many aspects such as human and material factors. The human environment includes corporate culture, organizational structure, human resources, etc. The physical environment includes mining resources, machinery, equipment, construction conditions, etc.

The mining area culture must converge with the enterprise culture. Only by recognizing the same values, will mining area management not deviate from the development strategy of the enterprise, and will there be no internal management contradictions. The management of the mining area should take the concept of safety as being paramount rather than profit as being the focus of work. Only by taking safety as the priority, can alarm bells ring at all times, preventive measures be taken and be targeted at key moments. Managers in the mining area should have certain academic qualifications and on-site work experience. Rich cultural knowledge and practical experience can help to make scientific and reasonable professional decisions and provide a guarantee for feasibility and safety. The work area should pay attention to the publicity of enterprise culture and construction safety. The process of spreading corporate culture is subtle. When people from top to bottom can recognize corporate culture, employees will have a sense of belonging, value and identity. This positive emotion is conducive to the development of all work and can also lay the foundation for all good results. Safety publicity work is essential. Only by constantly emphasizing and repeating can we get attention. A good control environment has a multiplying effect in the process of mining area management. To achieve safe, healthy, and sustainable development, management should pay attention to the construction of the control environment and build the management foundation.

2) Risk assessment

About 70% of China's mines are high gas mines, with high-risk coefficients and congenital deficiency of large risk loss. Therefore, in the management process, we should strictly control and evaluate potential risks, and formulate risk response plans in time to reduce risks and losses. The whole risk management process covers before, during and after the event. Pre-risk control should be familiar with the risks and set up a complete implementation plan; attention should be paid to the legal compliance of the management process, real-time assessment, timely prevention and control; post-event risk response should pay attention to personnel evacuation and human and financial protection.

3) Control activities

Control activities involve the most extensive content. The first is management authorization. The structural configuration of management in the mining area should ensure mutual restraint, and the powers and responsibilities are clear. Everyone can have a voice, but not everyone has decision-making power. The second is the assessment of performance. In the process of mine management, the results of the safety knowledge examination can be added to the performance evaluation. Office departments should organize training assessments on the basis of publicity work. Regular examinations are conducted on issues such as investigation, protection, operation, self-rescue, emergency response and early warning. The examination results are linked to wage performance. The purpose is to motivate employees to keep the concept of safety first in mind, and at the same time, when uncontrollable factors occur, emergency measures can be taken quickly. Employees should perform routine inspections of equipment before construction, shut down maintenance after construction, perform regular maintenance, discover hidden risks before they are realized, and update and replace them when they are due.

According to the results of risk assessment, control measures are taken with regard to the possibility of coal-rock dynamic disasters, such as eliminating outbursts, gas extraction, increasing ventilation, stress release, stopping mining and waiting for the relevant monitoring index to be normal, or even escaping immediately or hiding in the refuge chamber to reduce or eliminate the risk.

4) Information and communication

In the management of risk in the mining area, the characteristics of information and communication must be true, complete and timely. The data of ground temperature, gas pressure, gas concentration, dust content and surrounding rock stress should be updated in real-time and can be fed back to the ground service station synchronously to ensure that the technical personnel can be deployed in real-time after obtaining the latest information. Construction personnel should provide timely feedback on the underground state to the inspection personnel and technical personnel in the working area. The communication between the technical personnel and the construction personnel should be easy to understand and avoid ambiguity. Underground workers should cooperate tacitly, communicate actively, and ensure the effective transmission of information. During the handover of work, the work progress, site conditions, data content, etc. must be explained in detail. Workers should report daily work progress and construction to the safety leader in order to ensure that managers understand the situation of the mining site.

Information and communication is a bridge that connects the mining area horizontally and vertically. The effective transmission of information and smooth and effective communication plays a decisive role in business decision-making and safe construction.

5) Supervision

Supervision is the last barrier to mining risk management. All people in the mining area should supervise each other. Absenteeism should supervise each other whether there is an illegal operation phenomenon, or whether there is speculation about safety hazards in the work. Managers can perform a combination of regular and surprise patrol inspections during the operation of employees, find problems before accidents occur and take effective measures. Managers should also check and balance each other to ensure a clean and healthy source, which is more conducive to long-term development. Enterprises should supervise each mining area, visit them regularly, and understand the real-time situation in order to ensure appropriate policies. Supervision work is always accompanied by the operation of the mining area, and its role in preventing risks should be maximized.

In addition to the internal supervision of the organization, society should also supervise the mining area. On the one hand, it supervises the efforts made by the mining area for environmental protection, on the other hand, it supervises whether the safety management of the mining area is legal and compliant.

2.2. Risk management

Due to its special underground mining environment, various risk factors are constantly combined and developed, and enterprises have not adopted corresponding strategies, which eventually leads to the outbreak of risks in some form, resulting in casualties, property loss and the damage to reputation. The process is shown in Figure 4. Based on the internal con-

Fig. 4. Risk occurrence and development process
Source: own study

Rys. 4. Występowanie ryzyka i proces rozwoju

trol theory and the actual situation of mining areas in China, this section analyzes the risk management of mining areas.

2.2.1. Risk generation

Risks include both external risks and internal risks. External risks generally refer to natural disasters that enterprises cannot predict and control, such as earthquakes, thunderstorms and landslides etc. Internal risks are generally manageable and controllable, including human resource management risks, leadership decision-making deployment risks, and safety production risks.

1. Human resource management risk. There is mainly an unreasonable understanding of 'people' and unreasonable investment in development, unreasonable allocation of underground personnel, insufficient safety training, and special post-care for inspection technicians and mining logistics support staff.
2. Leader decision-making deployment risk. Leaders did not conduct in-depth research on the environment of grassroots posts in the upper and lower wells, they did not understand the real situation leading to decision-making errors, it was found that decision-making would cause losses or adverse effects which were not reported in time and they did not make new decisions to correct mistakes.
3. Safety production risk. There is insufficient safety awareness of personnel in mining areas, a failure of safety production facilities, illegal operation, the omission of intermediate procedures, a weak sense of responsibility of inspection technicians, and special areas have not received special attention.

2.2.2. Risk damage category

Failure to effectively manage risks and unreasonable decision-making after the formation of risks will likely cause damage, which mainly includes the following aspects.

1. Casualties. Risk damage caused by external risk and internal risk evolution may cause casualties.
2. Damage to downhole equipment. Underground mine earthquakes, rock bursts, coal and gas outbursts, coal mine water inrush, gas explosions, etc. can cause serious damage to the equipment and seriously affect the monitoring equipment and communication lines on the well.
3. Mining ground and surrounding residents damage. Building distortion or even collapse, ground subsidence caused by uneven settlement, water spray, and serious casualties.
4. Economic property and social evaluation. In the process of risk management, we should try to avoid the formation of risks at source, fully evaluate the risks before making decisions, reduce the possibility of risks and avoid unnecessary losses. In the case of already existent risks, close attention should be paid to risk dynamics, overall planning and decision-making deployment, and attempts should be made to eliminate or reduce the degree and scope of its impact. Risk management is aimed at the continuous and stable operation of the mining area and safe and efficient mining.

3. Mining risk management system based on internal control theory

3.1. Risk indicator principle

The safety risk is the primary entry point of the internal control system in the mining area. In accordance with the problem orientation and the five elements of internal control, the evaluation index is selected according to the principle of goal, comprehensiveness, scientificity, timeliness and focus.

1. Goal principle. The goal principle is the core of the establishment of evaluation indicators and the follow-up work is problem-oriented.
2. Comprehensive principle. The safety risk characteristics inside and outside the mining area should be comprehensively considered. With regard to the overall situation, the overall awareness and analysis ability should be improved, the responsibilities of the department should be refined, and the comprehensive principle of the establishment of evaluation indicators should be determined.
3. Scientific principle. Objectively select indicators, in line with the actual situation of the mining area, because there are more risk factors in the identification of quantitative decision-making implementation, reduce subjectivity, select scientific and effective risk identification methods for related index factors, quantify the risk level and improve the scientific nature of risk identification.

4. The principle of flexibility and timeliness. When the risk is contrary to the objective situation with the change in the internal and external environment, we should correct it in time, establish a dynamic management system and take timely measures to deal with risk.
5. Focus principle. In the identification of risk factors, the risk should be graded. Firstly, we should focus on dealing with high-risk factors and make effective weight decisions.

3.2. Risk management framework

In the high-risk environment of the mining area, ensuring personal and property safety is the primary task of the mining area. Based on the five elements of internal control theory,

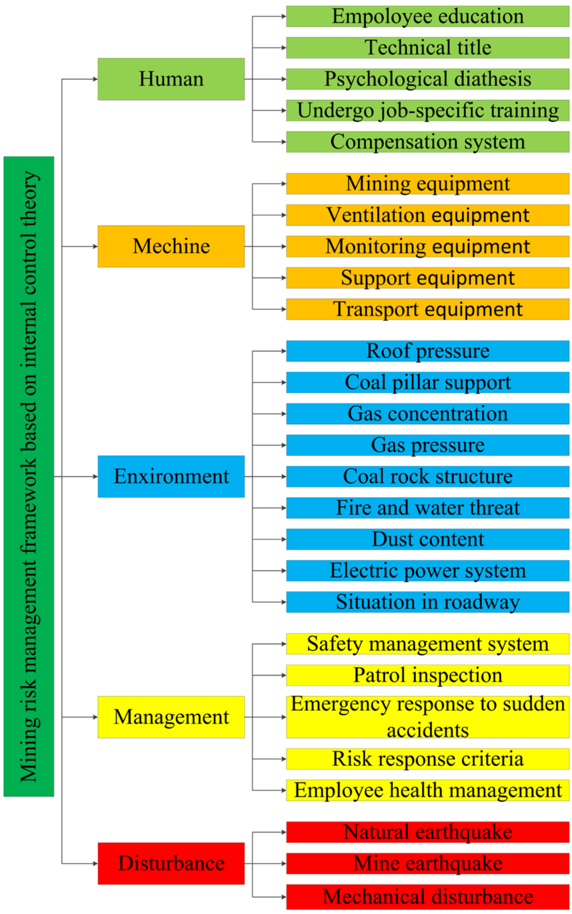

Fig. 5. Risk management framework of mining area under internal control theory
Source: own study

Rys. 5. Ramy zarządzania ryzykiem w obszarze górniczym zgodnie z teorią kontroli wewnętrznej considering five first-level risk indicators, a mining area risk management framework of human-machine-environment-management-disturbance is established and subdivided into twenty-seven second-level risk indicators and a more systematic and accurate internal control risk management framework is constructed, as shown in Figure 5, which provides effective support for subsequent mining area risk control and response measures.

3.3. Risk level

Different risk levels require different countermeasures. The classification of risk levels is based on the two dimensions of risk possibility and risk severity to jointly and qualitatively determine the risk level. Table 2 shows the analysis of the risk possibility and severity of the mining area, and determines the risk level of the mining area. The hierarchy is shown in Figure 6.

Table 2. Risk possibility and severity criteria

Tabela 2. Kryteria możliwości i dotkliwości ryzyka

Risk possibility	Description	Risk severity	Description
Scarcely possible	may occur under special circumstances	micro	no casualties and little property damage
Probably	happens in most cases	mid	more serious personnel injuries and greater economic losses
Defined	basic expectation occurs	magnum	casualties and huge economic losses

Source: own study.

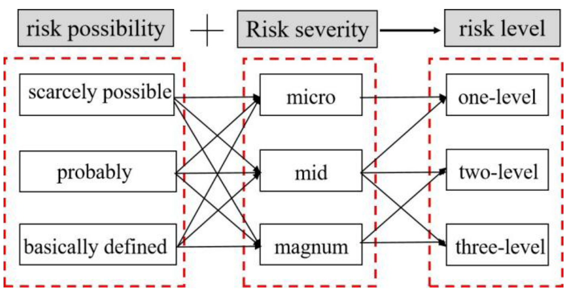

Fig. 6. Risk level determination criteria
Source: own study

Rys. 6. Kryteria określania poziomu ryzyka

3.4. Risk response

As a complex series whole, the risk of the mining area is universal and linked. Risk identification is the first step of risk management. It should first identify the existing or potential risks and determine the sources of hazards in the mining process.

Based on the results of risk identification, risk assessment provides an effective factual basis for the scientific and reasonable formulation of effective countermeasures through the scientific and reasonable assessment of risks by professionals and the above-mentioned risk classification.

Risk response is the key to reducing or eliminating risk and damage. According to the results of risk identification and assessment and risk response criteria, combined with on-site conditions and emergency decision-making and deployment, risk response measures are formulated to ultimately reduce or eliminate risks. The risk response process is shown in Figure 7.

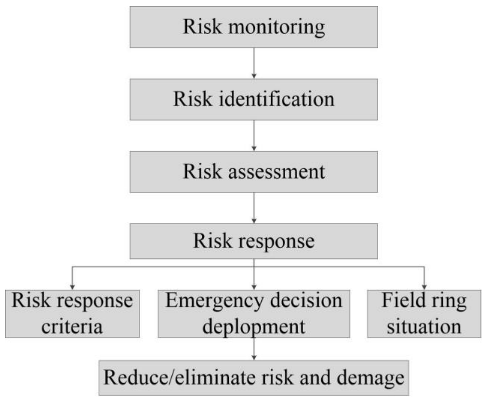

Fig. 7. Risk response process
Source: own study

Rys. 7. Proces reakcji na ryzyko

4. Problem-solving countermeasures

Based on the four key technologies, a dual prevention and control mechanism is formed around the system risk and post-risk management system to realize the prevention and control of the safety risks of coal mines and the containment of accidents. The problem-solving countermeasures are illustrated in Figure 8.

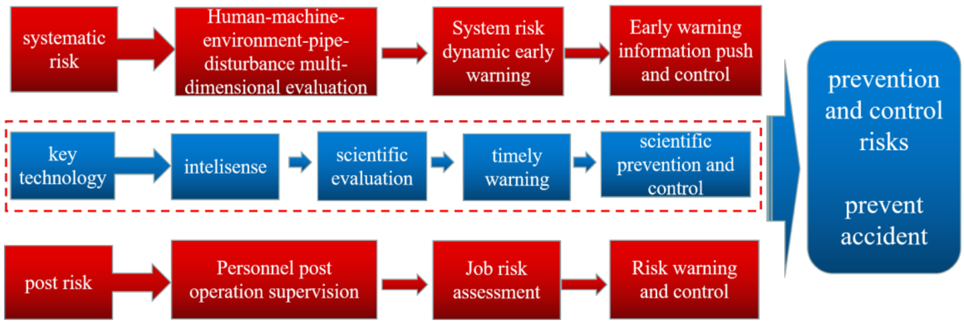

Fig. 8. Problem-solving countermeasures
Source: own study

Rys. 8. Środki zaradcze w rozwiązywaniu problemów

5. Discussion

Based on the five elements of internal control, a risk management system has been constructed, which is conducive to identifying risks in management from the source, so as to take targeted management and preventive measures. In fact, the results of the implementation of the five elements are ultimately reflected in the three major objectives, namely the reliability of financial reporting, the adaptability of laws and regulations, and the efficiency and effectiveness of operations. However, this paper does not study the three major objectives of internal control in depth. This is because the internal control management is generally based on operations, while this article is based on mine safety. Subsequent research can be combined with more dimensions such as safety, economy and legitimacy of mining areas.

After analyzing risk generation and risk damage categories, the risk indicators are selected and the risk management framework is established. After subdividing the risk level, the risk response process and problem solving countermeasures are proposed. Although the research perspective is comprehensive, there has been no specific empirical analysis of engineering applications and on-site investigations. Follow-up research should be combined with the actual situation of the site to effectively guide the safe production and management of the mining area.

Conclusion

1. Based on the five elements of internal control, this paper has systematically analyzed the problems existing in the risk management of mining areas under each element, the factors that induce risks, and the corresponding rectification measures.

2. Secondly, based on the actual characteristics of China's mining areas, the causes and damage categories of mining area risks have been analyzed with the aim of providing goal orientation for subsequent risk management.
3. In accordance with the five selection principles of the evaluation index and the five elements of internal control, the mining area risk management framework of human-machine-environment-management-disturbance has been established, and twenty-seven secondary risk indicators are subdivided to construct a more systematic and accurate internal control risk management framework.
4. Based on the risk management framework of the mining area under the internal control theory, the risk level determination criteria and risk response process have been established, and the risk management system of the mining area under the internal control theory has been formed. It provides new methods and new ideas for mine risk management.
5. Based on the four key technologies, focusing on the system risk and post-risk management system, a dual prevention and control mechanism has been formed to realize the prevention and control of coal mine safety risks and the containment of accidents.

This research was supported by the Key Project of the Natural Science Foundation of Heilongjiang Province (No. ZD2023E008).

REFERENCES

Hao, X. and Ren, Y. 2015. Research on assessment in dicator system of the safety and high efficient and green underground coal mine. *China Coal* 3(7), pp. 69–72.

He et al. 2016 – He, C., Li, X. and Wang, G. 2016. Design on Coal Mine Safety Supervision Index System for Safety Supervision Department. *Safety in Coal Mines* 4(2), pp. 235–237.

Li et al. 2009 – Li, S., Cheng, L., Jing, X. and Xu, C. 2009. Study on construction method of evaluation index system for safety in put of coal mine. *Journal of Safety Science and Technology* 5(5), pp. 93–96.

Li et al. 2020 – Li, S., Xue, G., Fang, X., Yang, Q., He, C., Han, S. and Kang, Y. 2020. Coal mine intelligent safety system and key technologies. *Journal of China Coal Society* 45(6), pp. 2320–2330.

Liu et al. 2013 – Liu, G., Qi, A. and Li, S. 2013. On the evaluation model and method of safety hazard integration management maturity of coal mine. *Journal of Safety and Environment* 5(12), pp. 244–250.

Meng et al. 2020 – Meng, S., Yang, W., Li, H., Wang, M. and Sun, Y. 2020. Preliminary study on the early warning of coal mine gas disaster induced by shake. *World Earthquake Engineering* 36(2), pp. 218–228.

Meng et al. 2022 – Meng, S., Mu, H., Wang, M., Yang, W., Liu, Y., Sun, Y. and Yuan, X. 2022. Characteristics and Identification Method of Natural and Mine Earthquakes: A Case Study on the Hegang Mining Area. *Minerals* 12(10), DOI: 10.3390/min121012561256.

Qiao, G. 2013. *A Study on the Coal Mine Safety Comprehensive Evaluation and Risk Warning Management Mode*. PhD thesis. China University Geosciences.

Sui et al. 2019 – Sui, W., Wang, D., Sun, Y., Yang, W., Xu, Z. and Feng, L. 2019. Mine hydrogeogical structure and its responses to mining. *Journal of Engineering Geology* 27(1), pp. 21–28, DOI: 10.13544/j.cnki.jeg.2019-072.

Wang et al. 2014 – Wang, J., Zhai, X. and Feng, L. 2014. Efficiency optimization of coal mine production on logistics under safety hard constraint. *Chinese Journal of Management Science* 7(13), pp. 59–66.

Xie et al. 2012 – Xie, H., Zhou, H., Xu, D., Hongwei, W., Ru, Z. and Feng, G. 2012. Research and consideration on deep coal mining and critical mining depth. *Journal of China Coal Society* 37(4), pp. 535–542.

Xu, D. 2022. Characteristics and occurrence regularity of coal mine accidents in China from 2020 to 2021. *Coal Engineering* 54(7), pp. 129–133.

Xu et al. 2020 –Xu, Z., Gao, X., Li, Z., Wu, T., Zheng, T., Wen, X., He, R., Li, H. and Wang, K. 2020. Investigation on Public Service Demand of Earthquakes Induced by Human Activities Including Mining and Reservoir Impoundment. *Earthquake Research in China* 36(3), pp. 630–638.

Yang, C. 2015. Study on the system of coal mine safety risk prevention and control based on internal control management. *China Coal* 41(7), pp. 120–123.

Yang et al. 2015 – Yang, J., He, F., Cui, T., Bai, R., Yu, Y. and Song, H. 2015. Safety analysis of coal mine disaster based on factor analysis. *Journal of Safety Science and Technology* 11(04), pp. 84–89.

You, D. and Qi, A. 2011. Safety integration management system of coal mining enterprise and its evaluation model based on ANP. *China Safety Science Journal* 1(14), pp. 60–65.

Yuan, L. 2017. Scientific conception of precision coal mining. *Journal of China Coal Society* 42(1), pp. 1–7, DOI: 10.13225/j.cnki.jccs.2016.1661.

Yuan, L. 2021. Study on the development strategy of coal mine safety in China. *China Coal* 47(6), pp. 1–6.

Yuan et al. 2018 – Yuan, L., Jiang, Y., He, X. and Dou, L. 2018. Research progress of precise risk accurate identification and monitoring early warning on typical dynamic disasters in coal mine. *Journal of China Coal Society* 43(2), pp. 306–318, DOI: 10.13225/j.cnki.jccs.2017.4151.

Yuan et al. 2020 – Yuan, J., Sun, R. and Yuan, X. 2020. Framework of risk governing of earthquake disaster for civil engineering. *Earthquake Engineering and Engineering Dynamics* 40(2), pp. 145–153.

Zhang et al. 2005 –Zhang, F., Yu, Z., Xu, X., Yang, W., Zhang, S., Liu, J., Liu, T. and Zhou H. 2005 Research on induced earthquakes by coal mining in hegang. *Journal of Natural Disasters* 1, pp. 139–143.

Zhang et al. 2022 – Zhang, J., Hou, T., Li, M., Li, P. and Gu, H. 2022. Mechanism and prevention measures of rock burst induced by dynamic disturbance in coal seam roadway. *Coal Engineering* 54(2), pp. 62–66.

Zhao, G. 2020. *Research on Internal Control Evaluation System of Safety Responsibility of Coal Enterprises-Take Shenhua Energy Co.*, Ltd. Master thesis. Xian University of Science and Technology.

Zhao, Z. 2022. *Identification of key risks of coal mine safety accidents based on cases and standards.* Master thesis. Zhongnan University of Economics and Law.

RESEARCH ON A MINING AREA RISK MANAGEMENT SYSTEM BASED ON INTERNAL CONTROL THEORY

Keywords

internal control, mining area, risk management system

Abstract

Based on China's resource endowment and coal mine disaster statistics, it has been found that there are many deficiencies in the management of disasters and risks in mining areas in China. Therefore, to scientifically and effectively manage mining areas, based on the theory of internal control, this paper systematically analyzes the risks of mining areas in the context of various factors and relevant suggestions. From the occurrence of mine risk to the occurrence of damage, the importance of risk management is highlighted. In accordance with the five selection principles of evaluation indicators (goal principle, comprehensiveness principle, scientificity principle, timeliness principle and focus principle) as well as the five elements of internal control (control environment, risk assessment, control activities, information and communication and supervision), a mining area risk management framework of human-machine-environment-management – disturbance is constructed, and twenty-seven secondary risk indicators are divided. The criteria for determining the risk level and the risk response process have been established, and a more systematic and accurate mine risk management system under the theory of internal control has been formed. Finally, based on four key technologies, a dual prevention and control mechanism is formed around the system risk and job risk management system. This provides new methods and ideas for the prevention and control of coal mine safety risks and the containment of disasters and accidents.

BADANIA SYSTEMU ZARZĄDZANIA RYZYKIEM OBSZARU GÓRNICZEGO W OPARCIU O TEORIĘ KONTROLI WEWNĘTRZNEJ

S ł o w a k l u c z o w e

kontrola wewnętrzna, obszar górniczy, system zarządzania ryzykiem

S t r e s z c z e n i e

Na podstawie chińskich zasobów i statystyk dotyczących katastrof w kopalniach węgla stwierdzono, że istnieje wiele niedociągnięć w zarządzaniu katastrofami i ryzykiem na obszarach górniczych w Chinach. Dlatego, aby naukowo i efektywnie zarządzać obszarami górniczymi, w oparciu o teorię kontroli wewnętrznej, w artykule systematycznie analizuje się ryzyko obszarów górniczych pod kątem różnych czynników i odpowiednich sugestii. Od wystąpienia ryzyka górniczego do wystąpienia szkód podkreśla się znaczenie zarządzania ryzykiem. Zgodnie z pięcioma zasadami wyboru wskaźników oceny: zasadą celu, zasadą kompleksowości, zasadą naukowości, zasadą terminowości i zasadą ukierunkowania, a także pięcioma elementami kontroli wewnętrznej: środowiskiem kontroli, oceną ryzyka, działaniami kontrolnymi, informacją i komunikacją oraz nadzorem, skonstruowano ramy zarządzania ryzykiem w obszarze górniczym w zakresie zakłóceń w zarządzaniu ludźmi, maszynami i środowiskiem oraz podzielono 27 drugorzędnych wskaźników ryzyka. Ustalono kryteria określania poziomu ryzyka i proces reagowania na ryzyko, a także stworzono bardziej systematyczny i dokładny system zarządzania ryzykiem kopalnianym w ramach teorii kontroli wewnętrznej. Wreszcie, w oparciu o cztery kluczowe technologie, stworzono podwójny mechanizm zapobiegania i kontroli ryzyka systemowego i systemu zarządzania ryzykiem zawodowym. Zapewnia to nowe metody i pomysły w zakresie zapobiegania i kontroli zagrożeń bezpieczeństwa w kopalniach węgla oraz ograniczania katastrof i wypadków.