The research of investment risk assessment and management on non-coal mine safety accidents

Xuemei Zhang, Yan Zhao

Xueyuan Road 29,Haidian District, Humanity Economic and Management College, China University of Geosciences, Beijing, China

Xueyuan Road 29,Haidian District, Humanity Economic and Management College, China University of Geosciences, Beijing, China

zhangxue_mei@126.com, 827116250@qq.com

Keywords: risk assessment, safety risk, safety cost, mine safety accidents, risk management

Abstract. The mineral resource is the basis for society development and helps human make progress. But the safety accidents happen frequently which causes the economic loss to the companies and damage to mining employees' work and life. So mine investors should assess the safety risk and make necessary security investment. This paper selects a sample to estimate the probability of accidents according to the historical data and calculate the loss of accidents. We try to provide a principle to evaluate the risk of safe investing. Based on the principles of cost-effectiveness, investors can weigh safety cost and safety investment. They should pursue the best safety investment and implement safety management.

Introduction

As an energy industry, mining is the foundation of national economy. It is also the support of other industries and has great influence on the economy. However, frequent accidents bring a lot of economic loss to the mine and physical damage to the workers. In recent years, the safety condition is constantly improving, but the whole situation is not optimistic. Large mine accidents is still ongoing and the mortality remains high. According to statistics, the mortality from mine is more than any other industry in our country. So how to identify and assess the risk effectively is a more important concern to the owners and investors.

After the analysis and assessment of mine risk, coal owners must take the safety investment into consideration to manage the safe risk effectively. But they cannot devote endlessly to pursue the maximum security because of the limited resource. Therefore the investors should consider more about the invest efficiency, follow the principle of cost effectiveness, and weigh the cost and benefit. Investors want to realize the more invest efficiency with a lower cost, so how to allocate resources reasonably and direct the investment has realistic significance.

Related Definitions

Safety Risk. The basic meaning of risk is uncertainty of loss. Now there is no consistent definition of risk. The common definition of risk has following kinds: loss opportunity and loss possibility; loss uncertainty; difference between actual and expected results; probability of actual results deviating from the expected results.

Mine safety is affected by many factors, such as mine environment, safety condition and workers' safety consciousness. The existence of security risk is sure, but the happening of risk is uncertain, including the uncertainty of time current situation and result. The paper defines the safety risk as the uncertainty of safety loss, namely the product of accident loss and possibility. General formula is following:

risk=hazard*probability.

Safety Cost. Now there is no unified safety cost accounting system in our country. Guoqing Yao (2001) put forward the safety cost and related accounting concept. Yue Zhu (2004) discussed the

composition of safety cost and the organizational forms and methods of accounting. And the author put forward the principles and calculation methods of safety cost.

This paper defined safety cost as following: the economic cost to realize safety production and economic loss from safety accidents. It includes ensure cost and loss cost.

Ensure cost is the cost to ensure safe production and reduce safety loss, such as the engineering cost, operation cost and safety management expense.

Loss cost refers to the economic loss from safety accidents which can be divided into direct loss and indirect loss. Direct loss contains compensation for casualties, damage of the fixed assets and expenses for reproduction. Indirect loss includes the shutdown loss, the bad influence to natural resources, social environment and the staff, the training expense for new staff.

Risk Assessment on Safety Accidents

Sample Selection. This paper focuses on safety incidents of our countries' non-coal mine and selects the larger accidents happened from 2001 to 2011 as samples. We divide the accidents into seven categories that are collapses, poisoning and choking, roof falls, blasting, gunpowder explosion and others. Accidents of others refer to incidents which have relatively few numbers, including vehicle damage, electric shock and so on.

Sample selects the larger accidents. Larger accidents mean the accidents which cause lots of casualty. The loss to the mines means the relative compensate to the casualty. So this paper uses the casualty to weigh the loss of the accidents.

Probability Distribution of Accident Frequency. According to the statistic information of mine accidents, this paper divides the accidents into seven types. The following is the statistic information.

Table 1 the number of non-coal mine larger accidents from 2001 to 2011

year \ types	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
collapse	47	36	30	38	20	21	28	20	10	9	10
roof falls	18	25	10	11	8	11	12	10	5	10	5
poisoning and choking	22	12	9	10	18	24	13	12	12	11	9
blasting	6	5	3	4	8	8	3	3	3	2	3
flooding accident	4	6	2	0	3	2	2	4	3	2	0
gunpowder explosion	4	1	3	3	2	2	2	4	2	0	2
others	13	6	11	19	13	7	19	10	9	9	1

Resource: Statistics Data of Research Institute of Information at State Administration of Work Safety

The random of mine accidents leads that the frequency of accidents is random. And there is no influence between the accidents. So the number of the mine accidents is a special kind of counting process. After the test of matlab, we found that the number of accidents in a year fits to Poisson distribution.

Therefore, the probability of number of accidents in a year is as follows:

$$P(k) = P(x = k) = \frac{e^{-\lambda} \lambda^k}{k!}$$

, that is the probability when the number of accidents in a year is k, the λ refers to the mean of number in a year.

Table 2 the statistic number of non-coal mine larger accidents from 2001 to 2011

	Min	Max	Average
collapse	9	47	24
roof falls	5	25	11
poisoning and choking	9	24	14
blasting	2	8	4
flooding accident	0	6	3
gunpowder explosion	0	4	2
others	4	9	11

Resource: Statistics Data of Research Institute of Information at State Administration of Work Safety

The Evaluation of Accident Risk. This paper selects the larger accidents which lead to lots of casualties. And the economic loss is the compensation from the civil organization. So we use the casualty to weigh the loss of accidents and use the average number to weigh the risk of every kind of accident.

The number of casualties' statistics of non-coal mine larger accidents from 2001 to 2011

types \ year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
collapse	194	136	109	128	79	82	107	79	30	31	45
roof falls	71	88	40	37	28	39	38	35	16	38	16
poisoning and choking	91	44	33	38	72	82	56	46	49	54	39
blasting	25	16	9	13	26	27	18	9	19	11	15
flooding accident	22	28	12	0	18	11	9	19	17	12	0
gunpowder explosion	17	3	12	11	12	9	8	14	12	0	6
others	123	74	76	97	114	73	100	89	78	56	24

Resource: Statistics Data of Research Institute of Information at State Administration of Work Safety

The average accident number of casualties each year from 2001 to 2011

types \ year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	average
collapse	4.13	3.78	3.63	3.37	3.95	3.90	3.82	3.95	3.00	3.44	4.50	3.77
roof falls	3.94	3.52	4.00	3.36	3.50	3.55	3.17	3.50	3.20	3.80	3.20	3.52
poisoning and choking	4.14	3.67	3.67	3.80	4.00	3.42	4.31	3.83	4.08	4.91	4.33	4.01
blasting	4.17	3.2	3.00	3.25	3.25	3.38	6.00	3.00	6.33	5.50	5.00	4.19
flooding accident	5.50	4.67	6.00		6.00	5.50	4.50	4.75	5.67	6.00		5.40
gunpowder explosion	4.25	3.00	4.00	3.67	6.00	4.50	4.00	3.50	6.00		3.00	4.19
others	4.54	4.50	3.91	3.84	4.46	3.71	3.42	4.70	3.33	3．67	3.00	3.92

Resource: Statistics Data of Research Institute of Information at State Administration of Work Safety

The paper uses N_i to express the mean casualty of each accident, i refers to the seven kinds of accidents. We suppose that compensation of one casualty is C, then the economic loss of one accident is CN_i, denoted as C_i.

According to the probability distribution of number of accident in a year and economic loss of one accident, we can conclude that the loss from the accident in a year is

$$L_i = \sum_{k=0}^{\infty} P(k)kCN_i = CN_i\lambda_i$$

, here i refers to the type of accident. We denote $L_i = C_i\lambda_i$. So we can include that the economic loss from the mine accidents equals to the sum of every kind accident,

that is
$$L = \sum_{i=1}^{4} L_i = C\sum_{i=1}^{4} N_i\lambda_i$$

Safe accidents risk management

After the risk assessment from mine accidents, investors or mine owners may concern more about how to reduce the accidents and manage the risk efficiently. When facing many choices to manage risk, the owners should make decision effectively and economically.

The mine accidents not only bring economic loss to the mine, but also let many families be in infinite grief and make the works more worried. The accidents have bad influence to the mine corporate and workers from the current to the long term. So we must take efficient measures for safe investing. At the same time investor should take the invest efficiency into consideration and weigh the efficiency and cost.

When the loss of the accidents is informed, investors should keep the cost in a established level to achieve the invest benefit.

If it is assumed that the accident risk will reduced by $Q\%$ after safe investing and the investing cost is C_0, then the mines' safety cost is $C_1 = L(1-Q\%) + C_0$. Let $C_0 = \mu L$, then $C_1 = L(1-Q\%) + \mu L$. If we don't take any measures, the safety cost is $C_2 = L$

When there are two choices, we need to compare the cost for final decision. That is to weigh the accidents reduction and the investing cost. If $C_1 < C_2$, then we can conclude $\mu < Q\%$. That means when the investing cost is less than the reduction of loss, we need to take safety measures for safety invest.

For every certain accident, we should also consider the cost and efficiency when making investing decision. If safety investing can let the risk reduce by $Q_i\%$ and the investing cost is $\mu_i C_i$, then the safety cost is $C_{1i} = (1-Q_i\%)L_i + \mu_i C_i = (1-Q_i\%)C_i\lambda_i + \mu_i C_i$. We assume that the safety cost without any investing is $C_{2i} = L_i = C_i\lambda_i$. When $C_{1i} < C_{2i}$, we can conclude $\mu_i < \lambda_i \times Q_i\%$. That means when $\mu_i < \lambda_i \times Q_i\%$, we should take measures for safety investing.

Summary

Mining industry is the base of economy. Its safe production affects people's life and the development of society. With rapid progress, government and enterprises pay more attention to the mine's safe production. For the mines' owners, their ultimate goal is maximizing the profits. So the operators tend to ignore the safety investment to pursue greater interest. They may think that the accidents won't happen and safety investment is a waste. But when safety accident occurs, it would bring huge economic losses to the mines and bad influence to social environment and miners' life. So mine investors should assess the safety risk and make necessary security investment.

Mine safety investment is a complex project. This paper provide a method for investors to estimate the probability of accidents according to the historical data and calculate the loss of accidents. So they can evaluate the risk of safe investing. Based on the principles of cost-effectiveness, investors should weigh safety cost and safety investment. They should pursue the best safety investment and implement safety management.

References

[1] Duzgun, Assessment and management of roof fall risks in underground coal mines. Safety Science (2004).

[2] Ke Jiashan, Feng Changgen, Chen Lang, et al. Analysis on decision support system of mine safety evaluation. Proceedings of the Second International Symposium on Safety Science and Technology (2000).

[3] Liu Yajing, Mao Shanjun, Li Mei, et al. Study of a Comprehensive Assessment Method for Coal Mine Safety Based on a Hierarchical Grey Analysis. Journal of China University of Mining & Technology (2007).

[4] Su Tongying, Sun Zhiqiang, Yang Ning. The Analysis of Coal Mine Safety Management Evaluation System. Proceedings of 2011 IEEE the 18th International Conference on Industrial Engineering and Engineering Management (2011).

[5] Tong Lei, Ding Rijia. Efficiency assessment of coal mine safety input by data envelopment analysis. Journal of China University of Mining & Technology (2008).