Research on safety risk management of civil construction projects based on risk matrix method

Yao Youli Peng Yingjian Li Xiaoxia Zhang airan

School of Coal Engineering, Shanxi Datong University, Datong Shanxi,037003

Abstract. In the view of the safety characteristics of open-air operation, high mobility and low safety quality of personnel in construction projects, in order to facilitate the systematic management of the safety risks of construction projects, the risk pre-control study of civil construction projects is carried out by using the risk matrix method in advance, the risk sources are identified according to the work task analysis method, and all work tasks and the specific processes of each task are listed in the form of a list. Identifying four types of hazard sources in all work tasks under existing working conditions, including human, machine, ring and pipe, and analyzing them using the risk matrix method, determining the risk value of the hazard sources and classifying the identified risk factors(hazard sources) by physical failure, human error, environmental factors and management deficiencies, It is convenient to take measures from management concept, technical method selection, organizational setting, staffing, system building and so on to improve risk management capability.

1. Safety risk characteristics of civil engineering projects

The construction of construction works is a running operation. The workplace and work content of construction works are dynamic and constantly changing. Each process can make the construction site change completely differently. With the progress of the project, the construction site may go from tens of meters underground to hundreds of meters above the ground. In the construction process, the surrounding environment, operating conditions, construction technology and so on are constantly changing, the safety problem of the construction process is also changing, and the corresponding security protection facilities often lag behind the construction schedule. Construction is very mobile, which is another characteristic of construction[1-4]. When a project is completed, the construction team is moved to a new location to build a new project. These new works may be in the same area or in another area, and the construction team will have to move accordingly between different areas. Construction is mostly open-air work, with heavy manual work mainly. The high intensity of construction operations, the noise, dust, the high temperature and cold on the construction site make the operator's physical strength and attention reduced. The wind, rain and snow weather will also lead to bad working conditions. Lack of night lighting will increase dangerous and harmful factors. In recent years, the construction project has been changing from industrial building to civilian building, the building from the lower level to the upper level, and the construction site from the wider to the narrow site. The difficulty of construction is increased, the risks and harmful factors change greatly, and many problems appear. The low technical content and non-standardized operation in the construction industry determine the relatively low quality of workers. The construction industry needs a lot of human resources, the employee and the construction unit short-term employment relation, which caused that the construction unit to the worker's education and training is seriously insufficient, which caused that the construction operation personnel lacks the basic safety production common sense, the illegal operation, the illegal command phenomenon happens occasionally.

The common safety risk in construction in our country is mainly caused by high fall, construction collapse, object strike, lifting injury, machine damage "five major injuries", and other safety accidents. There is a slight upward trend in the number of deaths from major accidents throughout the country, resulting in significant direct and indirect economic losses.

2. Risk Matrix method

In the process of production and service, there may be various kinds of hidden trouble of "man-machine-environment-management". If the hidden trouble is out of control, it will cause some loss. By risk assessment, all kinds of hazards in coal mine production activities are identified. The possible risks and consequences of hazards are clearly identified[5,6]. The hazards are classified by grades, monitored and forewarned. Corresponding measures are implemented to minimize the major risks and prevent accidents with minimal input.

According to the work task analysis method, the hazards are identified. First, all the work tasks and the specific processes of each task are listed in the form of a list. By the risk matrix method, hazards are analyzed. The risk value of the hazard can be calculated by which the probability of an accident is multiplied by the possible loss of the accident. It classifies the loss into six categories (i.e. A-F), with a decreasing assignment (1-6); The probability of an accident also falls into six categories (i.e. G-L), with a regressive assignment (1-6). Based on the size of the risk value, risk is divided into five levels, ranging from low to high, with levels I, II, III, IV and V, respectively, as shown in figure 1. The criteria for assignment of severity of consequences are shown in table 1 and the criteria for possible assignment are shown in table 2.

Consequences grade	F(6)	II	III	IV	IV	V	V
	E(5)	II	III	III	IV	IV	V
	D(4)	II	II	III	III	IV	IV
	C(3)	II	II	III	III	III	IV
	B(2)	I	II	II	III	III	III
	A(1)	I	I	II	II	II	II
		G(1)	H(2)	I(3)	J(4)	K(5)	L(6)
		Possibility level					
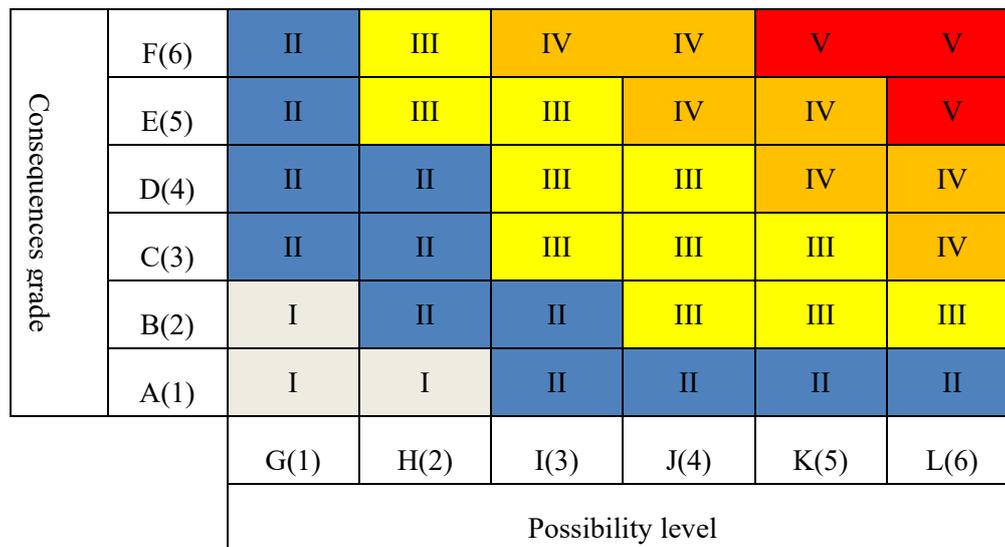
Figure 1. Risk matrix

Table 1. Assessment criteria for severity of consequences

category	assignment	loss	
		Level and extent of injury	loss due to injury
A	1	One person was slightly injured.	RMB 0 to 2000
B	2	One person is injured, requiring first aid, or multiple minor injuries.	RMB 2,000 to 10,000
C	3	One seriously injured.	RMB 10,000 to 100,000
D	4	Many people were seriously injured.	RMB 100,000 to 1million
E	5	One dead.	RMB 1 million to 5 million
F	6	Multiple deaths.	RMB Over 5 million

Note: Lower limit is included, upper limit is not included

Table 2. possibility assignment criteria

category	assignment	possibility	Measurement of possibility
G	1	impossible	Probably never happened.
H	2	Very little	It could happen once in more than 10 years.
I	3	Low probability	It could happen once in 10 years.
J	4	It could happen.	It could happen once in five years.
K	5	It can happen.	It could happen once a year.
L	6	It happens.	10 or more within 1 year

Level of risk is classified as follows, level I（<4）, negligible low risk, no action required; level II (4-8) is general risk; level III(9-16) is medium risk; level IV(17-25) is Significant risks; level V(>25) is particularly significant risks.

3. Apply instances

3.1. General situation of civil construction project of Sita mine

The construction area of industrial buildings is 18,186.8 m2, and the volume of construction is 128,447.7 m3. The total construction area of the mine administrative public building is 11,384m2, all newly built. The construction area of the industrial building is 18186.8 m2 and the construction volume is 128,447.7 m3. The total construction area of the mine administrative building is 113,84m2, all of which are new. According to the preliminary design data and production requirements of the Sita mine, the construction of the Sita mine is required for the construction of a new ground structure, which includes the main and secondary pit well shaft, the rubber well shaft, water supply facilities and the equipment and the construction equipment, ventilation room, yellow mud grouting station and reservoir, nitrogen production station and air compressor station, gas pumping station, daily fire pool and fire water pumping station, sewage treatment equipment and construction structures, administration and public buildings.

3.2. Identification and evaluation of risk factors

The risk matrix method is used to pre-control risk in the construction stage of civil engineering. The identified hazards are classified into faults of facility, personnel errors, environmental factors and management defects, so as to systematically manage the risks of construction projects, and take measures to improve the risk management capability in terms of management concept, technical method selection, organizational setting, staffing and system construction.

By using matrix risk analysis, we can identify the hazards in the various task processes of the construction of Sita mine. There are a total of 274 hazards, which are classified by man, machine, environment and management, as shown in figure 2. The proportion of man factors is the highest to reach 64.4 %, followed by the factors of machine. Therefore, we should add the control of the unsafe behavior in the various process tasks.
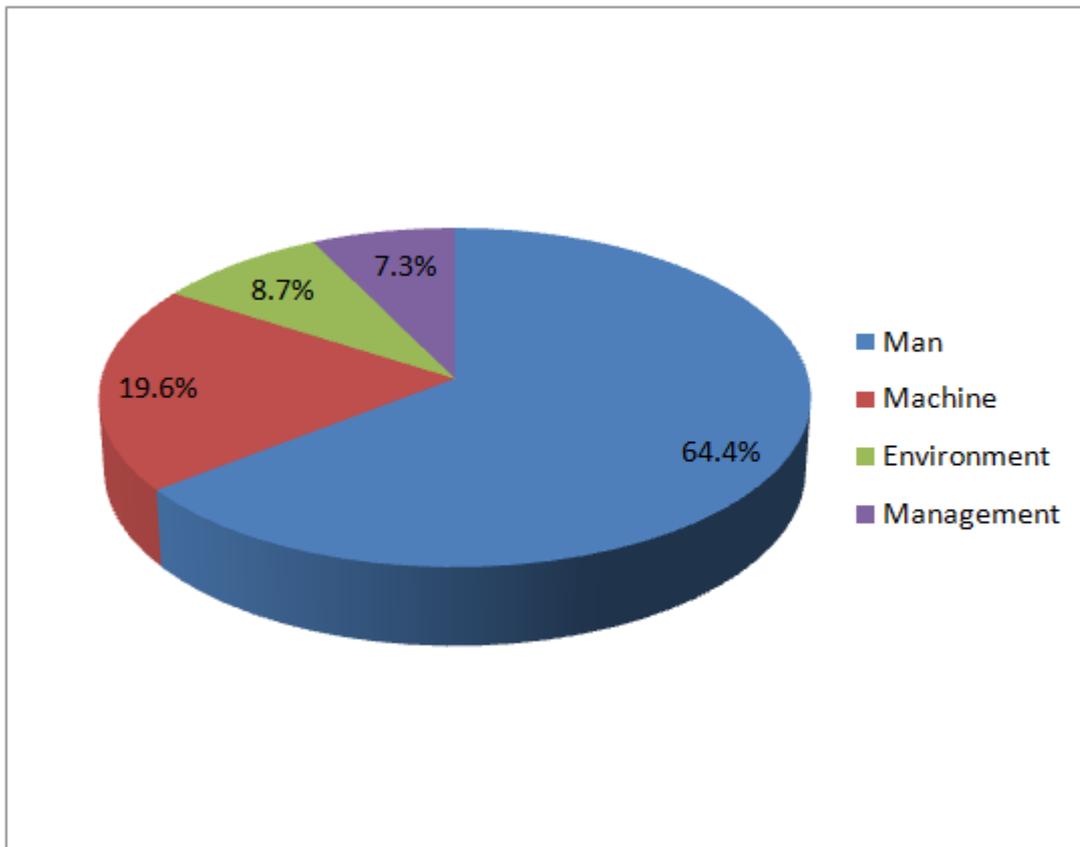
Figure 2. Classification of hazards

The risk matrix method is used to classify and rank risks in terms of "man-machine-environment-management", with 73 significant and above risk tasks, 160 medium risk tasks and 41 general risk tasks(see Figure 3).
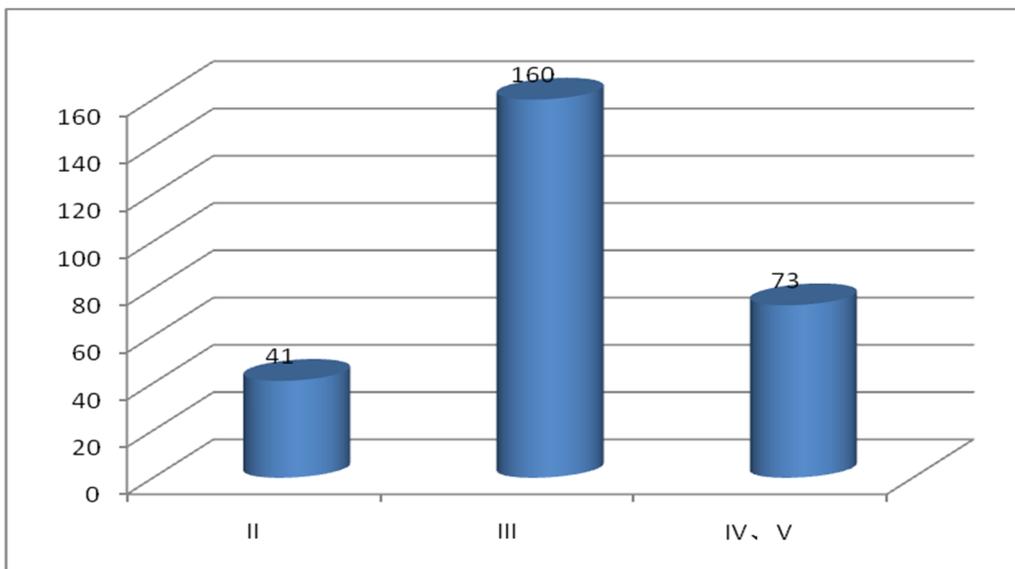

Figure 3. Statistical Chart of the Risk Level of Some Hazards in the Construction of Sita Mine

According to the above analysis, the hazard factors above the III level may result in collapse, fall and electrocution. The causes of collapse are Geological conditions, slope and scaffolding. The main trigger condition of high fall accident is the defect of safety protection. The cause condition of electric

shock accident is that the line and equipment of construction site have not been laid according to the regulations and take measures to protect ground connection. This shows that it is most important to prevent and control the collapse, fall and electrocution accidents in the construction stage of civil construction project, especially to carry out the key inspection of various safety and protection facilities, and also to eliminate the "three violations" operation of the construction personnel, and strictly investigate the special operation qualification certificate of the special operation personnel.

4. Conclusion

The risk matrix method comprehensively considers the risk impact and the risk probability, and each of them can directly assess the impact of risk factors on the project. To assess the safety risk of construction projects by determining the level of risk impact and risk probability in advance and judging the quantitative level of risk impact and risk probability by experts through more intuitive experience. The risk factors identified are classified according to fault, personnel error, environmental factors and management defects, so as to facilitate the systematic management of the safety risks of construction projects. Measures should be taken to improve risk management capability in terms of management concepts, technical methods, organizational structure, staffing, and institutional development.

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