

Comparison of Safety Risk Identification of Bridge and Tunnel Engineering

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Abstract. With the development of science and technology and the changes of the times, the transportation industry is developing rapidly all over the world. As a key and difficult project in the transportation industry, the bridge and tunnel project has many problems, such as complex engineering structure, large building scale, long construction period and changeable construction environment, which leads to frequent bridge and tunnel construction accidents. Based on the domestic and international theoretical research of risk management and safety risk, this paper adopts LC risk identification method to identify and horizontally compare safety risk accidents of bridges and tunnels in the same project. The aim is to figure out the difference of construction safety risk types between bridge and tunnel projects. It is significant to improving the efficiency of construction safety management via refining the evaluation indexes and comparing and analyzing the evaluation results from multiple angles.

Keywords: Bridge Engineering, Tunnel Engineering, Risk Management, Risk Classification, Risk Identification.

1. Introduction

As key and difficult projects in highway engineering, bridges and tunnels have complicated engineering structures, large-scale buildings and long construction period, which greatly increases the difficulty of construction[1]. All kinds of uncertain factors make bridge and tunnel construction accidents happen frequently. By 2020, bridge and tunnel accidents in China have accounted for 60% ~ 80% of the total number of highway accidents. Because of the complexity of bridge and tunnel engineering, there are great differences in construction technology and construction environment. Different projects have different types of functional devices, even though the functions and attributes are roughly the same[2]. Due to the influence of the project itself, the environment, the construction area and other factors, the identification and control of safety risks are complex and diverse.

Through horizontal comparison, this paper uses LC risk identification and evaluation method to investigate and identify the risk sources of two typical construction projects of tunnels and bridges in expressways. Taking targeted improvement measures according to different differences can better identify the similarities and differences of bridge and tunnel engineering safety risk identification, strengthen the ability to identify and control safety risks at the same frequency, effectively improve the safety management efficiency of road and bridge construction, and eventually reduce the occurrence possibilities of safety accidents.

1.1 Risk and risk management

The concept of risk was first born in the western economic field, and now it has been popularized in many scientific aspects such as engineering science, environmental science and disaster science. Although different fields focus on risk from many factors, risk has two basic characteristics, namely uncertainty and loss. The elements of risk include risk factors, risk events and risk losses [3-4]. Risk factors, risk events and risk losses are the basic elements of risk. Risk factors are the necessary conditions for the formation of risks and the premise for the emergence and existence of risks. The main contents of risk management include risk identification, risk assessment and risk control.

1.2 Security risk

Safety risk is a kind of risk, and bridge and tunnel safety risk is a subordinate part of safety risk. The meaning of safety risk is the safety production benefit that may be obtained because there is no proper safety investment, which may cause harm to the producer's life, loss of property, damage to the environment and other costs, etc., or because safety technical measures are adopted and a certain production expenditure is invested[5]. Compared with general construction projects, highway bridge and tunnel projects have the characteristics of complicated procedures, complicated operation, high technical level and great environmental impact, so the risks faced in the construction process are higher and more uncontrollable[6].

1.3 Security risk level

Safety risk grade is to divide safety accidents into different grade standards according to various factors such as the possibility and loss of safety accidents[7]. In the UK, the British Safety and Health Executive (HSE) classifies accidents into three levels: 1. major accidents that endanger people and cause one or more deaths; 2. general accidents that refer to the accident in which the person is slightly injured and does not go to work for three days; 3. attempted accidents which mean an accident that is dangerous but does not cause personal injury. In China, according to the relative regulations of Investigation and Handling of Production Safety Accidents, construction safety accidents are divided into four grades: particularly serious accidents, major accidents, major accidents and general accidents. If the above two or more conditions are met at the same time, the risk level shall be determined to according the highest level. From this, the difference and focus of risk classification can be seen between China and Britain.

1.4 Classification of safety risk accidents

Safety accident classification is an important step of risk identification, and it is a prerequisite to ensure the accurate development of safety management. The International Labour Office (ILO) carried out a lot of work on accident classification. In 1923, at the first international conference of labor statisticians convened by ILO, a resolution was adopted to classify accidents, and the accident categories were divided into 13 categories. According to the classification method formulated by American National Standards Institute (ANSI) in the United States, each important factor of an accident belongs to one of the following seven categories: 1. the Nature of injury; 2. Injured parts; 3. Source of damage; 4. Type of accident; 5. Hazard conditions: knowledge 6. Causes of accidents 7. Unsafe actions. China's "Classification of Casualty Accidents of Enterprise Employees" (GB6441-86) divides the dangerous and harmful factors into 16 categories: poisoning and suffocation, object attack, physical explosion, vehicle injury, chemical explosion, mechanical injury, gunpowder explosion, lifting injury, blasting, electric shock, collapse, falling from a height, burning, fire and other injuries. Although the two methods have different angles for risk classification, they can all provide a standard basis for risk classification.

2. Methodology

Three research methods are mainly used in this study: case method, comparative analysis method and LC risk identification method.

2.1 LC Risk identification method

Risk assessment is to use qualitative or quantitative methods to estimate the possibility and severity of risk accidents. Risk size = accident probability × accident severity.

In the LC risk identification method, the above evaluation principles are followed, and the risk level is mainly determined by the possibility (L) of risk events and the severity (C) of consequences.

The calculation formula is: $D = L \times C$.

Calculate the value of risk level, and finally divide the risk level corresponding to each risk event according to the result.

2.1.1 Classification standard of possibility index

Possibilities are uniformly divided into five levels, namely: extremely high, high, medium, low and extremely low.

Table.1. Possibility index grading value table

Possibility level	Possibility of occurrence	Value interval
Polar altitude	Extremely easy	(9-10]
Tall	Easy	(6-9]
Medium	Probably	(3-6]
Low	Unlikeliness	(1-3]
Extremely low	Extremely unlikely	(0-1]

2.1.2 Grading standard of consequence severity

The severity of the consequences is uniformly divided into four levels, especially serious, serious, relatively serious and not serious.

Table.2. Value Table of Severity Level of Consequences

Severity level of consequences	Consequence severity value
Particularly serious.	10
Serious	5
More serious	2
Not serious	1

The risk level (D) is determined by the probability (L) and the severity (C) of the risk event. The formula is $D=L \times C$.

According to the consequences and probability that may lead to safety accidents, the risk levels are divided into four levels: major, major, general and minor from high to low.

Table. 3 .Risk grade value interval table

Risk level	Risk grade value interval
Major risk	(55,100]
Greater risk	(20,55]
Ordinary risk	(5,20]
Low risk	(0,5]

2.2 Case method

Case Analysis Method, also known as case study method, was developed by Harvard University in 1880, and then used by Harvard Business School to train senior managers and management elites, gradually developing today's "case analysis method". Case study is a kind of field research. Researchers choose one or several scenes as objects, systematically collect data and materials, and conduct in-depth research to explore the situation of a certain phenomenon in the real life environment.

2.3 Comparative analysis method

Comparative analysis is a traditional method, and comparative method is a research method to find out the differences and commonalities between things. By comparing the same or different characteristics between things, objective things are compared, so as to know the essence and law of things and make a correct evaluation[8]. American scholar Kulan pointed out: Comparison means understanding a certain thing or field in comparison with other things or fields. As long as there are other different things, comparison must exist[9].

2.4 Case selection

The selected case in this paper is the bridge and tunnel project of Dehong-Menglian Expressway, with a total length of 101.789km, among which has 73 bridges (21.506km) and 22 tunnels (41.436km) in the main line. The ratio of bridges and tunnels in the main line reaches to 61.84%. The terrain is complex, the proportion of bridges and tunnels is large, and the requirements for construction organization and management are high. The location of the line has complex terrain and high construction technical requirements.

3. Selected Results

3.1 Comparison of risk event types and quantities

By comparing the number of risk events in bridge and tunnel engineering, it can be seen that the types of risk events that occur more in bridge operation are mainly lifting injury, falling from above and electric shock. The main types of risk events in tunnel operation are object impact and collapse. It is obvious that the number of risk events in bridge and tunnel engineering are concentrated in three categories: object strike, falling from a height and electric shock based on Figure 1.

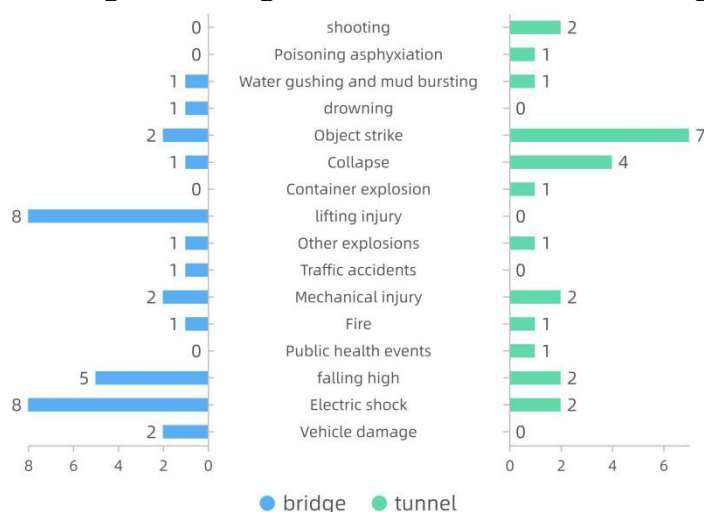


Figure 1. Comparison of the number of bridge and tunnel risk events

3.2 Comparison between probability and severity

Taking the possibility of accidents as an index, the possibility of accidents in bridge and tunnel engineering are compared horizontally. Through chart analysis and comparison, the probability of occurrence of the same type of risk events in different operating units of the same project is roughly the same. For convenience of comparison, the average probability of occurrence is taken for comparison in statistics, and the value is rounded up.

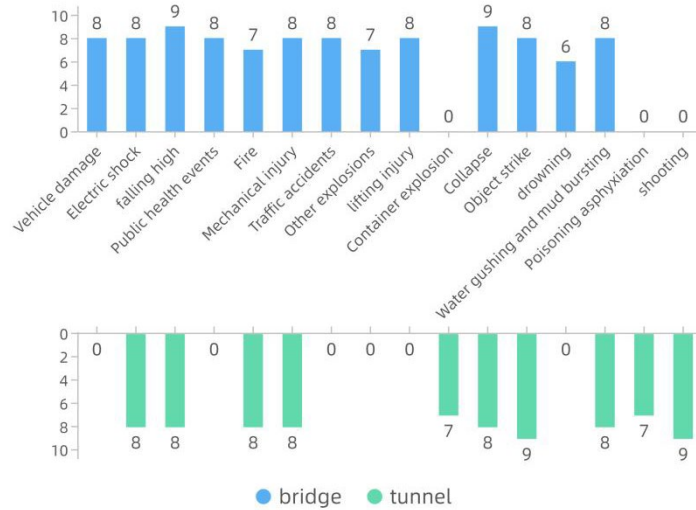


Figure 2. Comparison of the possibility of bridge and tunnel risk events

According to Figure 2, the probability of occurrence of risk events is between 7 and 9, the probability level is "high", and the probability of occurrence is "easy". These risk events all belong to the same level of occurrence possibility.

Figure 3 below shows the distribution statistics of risk events with different severity in bridge and tunnel projects. As can be seen from the figure, the risk events of bridge engineering with "serious" consequences mainly include falling from a height, object impact, collapse, mechanical injury and lifting injury. Tunnel risk events with "serious" consequences are mainly fire, object attack and blasting. However, the risk consequences of accidents are "serious" incidents, bridge projects are collapse and traffic accidents, and tunnel projects are collapse, water gushing, mud gushing and poisoning suffocation. Among them, collapse is a common type of "serious" consequences of two risk events.

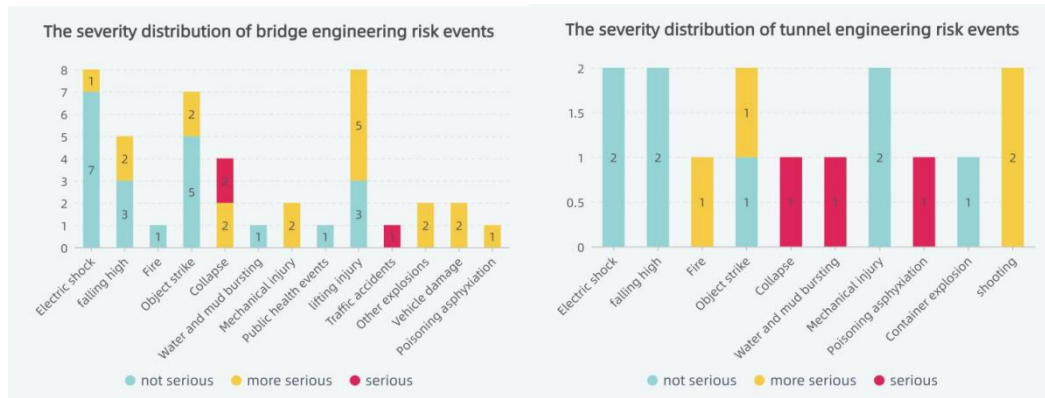


Figure 3. The severity distribution of bridge and tunnel risk events

3.3 Risk level analysis

By comparing the risk events of bridge and tunnel projects according to the same type, the most common risk types are: lifting injury, object strike, falling from a height and electric shock. The most prominent of the larger risks is collapse. Other types of risk events also exist. Judging from

preliminary lifting injury, object impact, falling from a height, electric shock and collapse is typical types of risk events in bridge and tunnel engineering.

4. Conclusions

4.1 Difference of types of safety risk events in bridge and tunnel engineering

Through the comparison of the types of risk events in different working units of bridge and tunnel engineering, the types of risk events between them have something in common, and there are common risk events. Electric shock, lifting injury and object strike are the three types with the largest number of risk events in bridge and tunnel engineering. Among them, the types of high risk events in bridge operation are electric shock, falling from a height and lifting injury. High risk events in tunnel operation are collapse and object impact. Because of the difference of construction technology and construction environment between them, they also have their own safety risk accidents caused by construction environment and construction technology, such as high fall and lifting injury in bridge engineering; Collapse, blasting and object strike in tunnel engineering. These types of risks belong to specific risks, which is prominent risk events in the corresponding operation units of bridges and tunnels. Because this study is only aimed at the bridge and tunnel project in Mengrui Gaosui Highway, there may be individual particularity of the case and the probability of accidental events, which can't prove the obvious difference between bridge and tunnel and the types of engineering risk events. However, from the literature review in the second chapter and the results of this study, it can be preliminarily seen that there are the same and common risk event types in bridge and tunnel engineering, and there are also their own prominent specific risk event types.

4.2 Comparative analysis of differences

The possibility of bridge and tunnel risk events in the case is compared and analyzed. After the surveyed risk events are identified by LC risk assessment, the probability L value of risk events in bridge and tunnel engineering are between 7 and 9, with the probability level of "high" and the probability of occurrence of "easy". These risk events all belong to the same level of occurrence possibility.

By comparing and analyzing the severity of the consequences of bridge and tunnel risk events in the case, in terms of the severity of risk events, the severity of bridge and tunnel risk events is "not serious" and "more serious" almost half of the total, and the severity of risk events is only a small part. The types of risk events with severe consequences of bridge and tunnel projects are also different, which further reveals the differences of specific risk events in the comparison of bridge and tunnel projects.

By comparing and analyzing the risk levels of bridge and tunnel risk events in the case, general risks are concentrated on four types: lifting injury, object strike, falling from a height and electric shock. The most prominent type of large risk is collapse; Traffic accident, poisoning and suffocation each exist. It is preliminary judged that falling from a height and lifting injuries are common risk events in bridge engineering; and collapse and object attack are common risk type in tunnel engineering. The four risk event types, lifting injury, object impact, falling from a height, electric shock and collapse respectively, are common common common risk types. Collapse is a type of high risk.

4.3 Research limitations

The safety risk identification and different analysis of bridge and tunnel engineering are beneficial to improve the risk management efficiency of highway engineering construction. Because of the complexity of bridge and tunnel engineering, there are great differences in construction technology and construction environment. Generally, the safety risk management of bridge and tunnel is discussed separately, while most large-scale traffic engineering projects involve both, but the key traffic engineering often involves the combination of bridge and tunnel. At present, there is little

research on the combination of highway bridge and tunnel risk identification at home and abroad, and there is no specific theory and system to put them together for risk identification and comparison.

Although this paper attempts to identify and compare the risk events in the construction stage of expressway bridges and tunnels by adopting a unified identification method, and has done some induction, summary and research on the comparison results, there are still many problems that need further research and exploration due to my limited field construction experience and few case data samples.

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