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# Safety risk Assessment for Construction of Highway on Plateau Mountainous

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**Abstract.** Under the condition of high altitude and complicated geological environment, lots of risks existing in the process of highway construction, how to control effectively safety risk has become the serious problem. Taking the construction project of Sichuan-Tibet highway as an example, combining with regional environment, safety risk indicators of construction project for plateau mountain highway is constructed. Method of construction safety risk assessment for plateau mountain highway is established. The feasibility of the evaluation method is verified by a case, and corresponding risk control measures are put forward.

## 1. Introduction

Sichuan-Tibet highway is located on the Qinghai-Tibet Plateau with deep mountains and valleys. The terrain is steep. In case of rain or snow melting, the road is prone to debris flows, landslides and other disasters. It is known as "Encyclopedia of Road Diseases". The characteristics of Sichuan-Tibet Highway determine that the construction project of Sichuan-Tibet Highway is faced with great safety risks. Frequent disasters are easy to cause great harm to the construction site, such as debris flow, landslide and flood. Although the experts have carried out the researches on the causes, prevention and risk analysis of geological hazards on Sichuan-Tibet highway<sup>[1~5]</sup>, it has become an urgent problem to evaluate safety risk of highway construction under complex geological conditions on the plateau highway. According to the characteristics of construction project of Sichuan-Tibet highway, this paper evaluates construction safety risk. Corresponding safety risk control measurements are proposed.

## 2. Risk assessment index system

### 2.1 Construction safety risk identification

Highway construction is not only affected by the poor construction environment of plateau hypoxia, but also often encountered landslide, collapse and other geological disasters. The paper analyzes construction safety risk of plateau highway, taking Sichuan-Tibet highway as an example. Through field investigation, safety risks of plateau highway construction are sorted out, and various risk analyses are shown in table 1.

Table 1. Construction safety risk classification of Sichuan-Tibet Highway

Risk categories	Risk analysis
Disaster risk	There are many disasters, such as landslide, collapse, debris flow and water destruction.
Plateau risk	14 precipitous high mountains with an altitude of more than



	4000 meters, and more highland roads with an altitude of more than 3000 meters.
Project risk	The construction works include two Bridges, four tunnels, high slopes and anti-slide piles.
Social risk	There are some people's living areas along Sichuan-Tibet highway, the impact of construction on people should be minimized.
Manage risk	Due to the geographical restrictions, safety management experience of large projects is less.
Economic risk	Transportation of construction materials is inconvenient.

## 2.2 Risk assessment indicators

In accordance with the principles of risk assessment indicators such as scientific, completeness, feasibility and conciseness, etc. According to actual situation of plateau highway construction projects, risk assessment indicators of six categories existing in the highway construction projects are sorted out to evaluate the risks, as shown in table 2.

Table 2. Risk assessment indicators

Risk categories	Risk factors
Disaster risk	Landslide, collapse, water damage and other disasters.
Plateau risk	Altitude hypoxia (altitude sickness).
Project risk	Technical risks of bridge construction, tunnel construction, high slope construction.
Social risk	Communicate with local residents, the pressure of construction, etc.
Manage risk	Construction of safety management system, management of large equipment, etc.
Economic risk	Construction material transportation is not smooth.

## 3. Risk assessment method based on risk matrix

### 3.1 Selection of risk assessment methods

Risk matrix method can identify the importance of risk. According to the definition of risk, a risk matrix table is constructed, as shown in table 3.

Table 3. Risk matrix

Risk category	Risk factor	Risk impact		Probability	Risk level	
		Quantized value	Grade		Grade	

The risk column mainly identifies and describes construction safety risks of Sichuan-Tibet highway. The impact column refers to the impact of such risks on the safety of highway construction, including quantitative value and grade, which is generally divided into four influence levels. Probability column is the probability of the occurrence of such risks. The risk level column includes quantitative value and grade, which is jointly determined by the impact column and risk probability. It is divided into four risk levels.

### 3.2 Identify risk column

According to risk analysis, the risk column includes disaster risk, plateau risk, engineering risk, social risk, management risk, economic risk.

### 3.3 Determine the impact column

The impact column describes impact degree of each risk on the highway construction project. The expert scoring method is used to determine risk impact level. Generally, it is divided into four grades. See table 4 for details.

Table 4. Risk impact level and quantitative value

Grade	Explain
Negligible	The impact on the safety of highway construction can be ignored.
Commonly	The risk of impact on safety of highway construction increases slightly, and the project construction can be carried out normally.
More	The risk of impact on the safety of highway construction is increased to a certain extent. Safety risk of project construction is affected, which may induce the occurrence of casualty accidents.
Major	The construction safety risk increases greatly, once the risk occurs, it will lead to the occurrence of major accidents.

The degree of risk influence was investigated by the experts. Taking the whole project or a certain bid section as the object of risk assessment, construction safety risk assessment of its environment and engineering situation are carried out.

### 3.4 Determine the probability column of risk occurrence

Due to great uncertainty of risk itself, there is a lack of historical data for corresponding statistics. Therefore, risk probability is mainly obtained by the expert survey method, as shown in table 5.

Table 5. Probability and description of risk occurrence

Grade	Quantized value	Explain
Probably	[3,4)	Production safety accidents are likely to occur
Probably	[2,3)	Increased possibility of production safety accidents
Accidental	[1,2)	The possibility of production safety accident is small
Not likely	[0,1)	Production safety accidents are extremely unlikely to occur

### 3.5 Determine the risk level column

According to the characteristics of safety risk in highway construction, safety risk is divided into four levels, namely low degree risk, moderate risk, height risk and extremely high risk. The risk level comparison table is shown in table 6.

Table 6. Risk level comparison table

Risk impact \ Risk probability		Negligible [0,1)	commonly [1,2)	more [2,3)	major [3,4)
Probably	[3,4)	Moderate	Height	Extremely high	Extremely high
Probably	[2,3)	Moderate	Height	Height	Extremely high
Accidental	[1,2)	Low degree	Moderate	Height	Height
Not likely	[0,1)	Low degree	Low degree	Moderate	Height

### 3.6 Clear risk acceptance criteria

According to safety risk level of highway construction, referring to the risk acceptance criteria at home and abroad, the risk acceptance criteria and treatment measures are proposed. The acceptance criteria and measures comparison table are shown in table 7.

Table 7. risk acceptance criteria

Risk level	Color identification	Acceptance criteria	Treatment measures
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Low degree	Blue	Negligible	There is no need to take risk treatment measures and monitoring.
Moderate	Yellow	Acceptable	Generally, it is not necessary to take risk treatment measures, but it needs to be monitored.
Height	Orange	Not expected	Risk treatment measures must be taken to reduce the risk and strengthen the monitoring. The cost of risk reduction should not be higher than the loss after the risk occurs.
Extremely high	Gules	Unacceptable	We must attach great importance to it. Feasible measures are taken to avoid it and strengthen monitoring.

#### 4. Example application

The construction project of Sichuan -Tibet highway is 20.6 km long. Two super large bridges and four tunnels are newly built. Along the line, there are deep and steep valleys along the river. Construction environment is complex, and construction safety risk is high.

Construction project is selected to carry out demonstration evaluation to test the feasibility of evaluation method. In order to fully understand construction environment and analyze risk situation, the research group went deep into the construction site to investigate. Main risks of the bid in the following aspects are shown in table 8.

After statistical analysis, according to classification standard of risk impact level, construction safety risk impact degree of bid section is determined, as shown in table 4. Combined with specific construction environment and construction team capacity, construction safety risk probability is determined according to risk occurrence probability standard and referring to table 4 (four levels). According to the risk level comparison table, risk level of each factor is determined, as shown in table 9.

Table 8. Main safety risks

Classification	Site layout	Main safety risks
1	Site layout	The influence of flood on construction safety
2	Construction of structures	Tunnel construction problems (water inrush, mud gushing, collapse, etc.), bridge construction problems, high slope safety issues, debris flow, collapse and other sudden natural disasters.
3	Transportation	The main problems are vehicle traffic guarantee, equipment transportation, tunnel entrance and exit safety

Table 9. Construction safety risk assessment of a bid section

Risk categories	Risk factor	Risk impact level	Risk probability	Risk level
Disaster risk	Debris flow	Major	Accidental	Height
	Landslide	Commonly	Probably	Height
	Collapse	Major	Probably	Extremely high
	Avalanche	More	Not likely	Low degree
Plateau risk	Water damage	Major	Accidental	Height
	High altitude hypoxia	Major	Risk probability	Moderate
	Easy to fatigue	Commonly	Accidental	Moderate
Project risk	Risk of bridge lifting	Major	Accidental	Extremely high

	operation		probably	
	Collapse risk of large bridge equipment	Major	Accidental	Height
	Falling risk of bridge working at height	More	Probably	Height
	Instability risk of tunnel portal excavation	Major	Accidental	Extremely high
	Risk of water inrush in tunnel excavation	Major	Accidental	Height
	Collapse risk of bridge high slope excavation	Major	Accidental	Height
Social risk	Communication with local residents	More	Probably	Hheight
	Pressure of construction	Major	Accidental	Extremely high
	Construction of safety management system	More	Accidental	Height
Manage risk	Experience of safety management personnel	Major	Accidental	Height
	Operation personnel quality	Major	Accidental	Height
	Large scale equipment management	Major	Probably	Extremely high
Economic risks	Poor transportation of construction materials	More	Probably	Height
	Material prices rise	More	Accidental	Height

According to risk acceptance criteria, the risk level of construction is very high, practical measures are taken to control the risk, mainly include: mountain collapse risk, complex construction of suspension bridge, tunnel construction under complex geological conditions, safety management of special or large-scale equipment used in the construction site, etc.

## 5. Conclusion

In order to strengthen highway construction safety and risk management in plateau mountainous area, taking Sichuan-Tibet highway reconstruction project as an example, this paper systematically analyzes potential risks in highway construction process. The risks are identified include disaster risk, plateau risk, engineering risk. The superposition of these risks determines high risk of plateau highway construction safety. In view of various risks encountered in the construction process, risk assessment model of construction safety is constructed based on risk matrix method, which provides technical reference for highway construction safety risk assessment in plateau mountainous areas.

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