Risk identification of expressway project management based on WBS method

Jiayu Liu*

College of Economics and Management,Taiyuan University of Technology,Jinzhong, China

*Corresponding author: liujiayu4241@link.tyut.edu.cn

Abstract. With the rapid development of science and technology and the acceleration of people's life rhythm, the emergence of expressway is of great significance to the progress of our country. Based on the characteristics of expressway construction, the identification of risks is particularly important. Based on WBS method and combined with FMEA analysis method, this paper proposes a risk identification method for expressway. Taking Xiyu expressway as an example, the specific application of the method to Tuhe super large bridge is carried out. After the project is decomposed, the risk source is identified, and the experts score the project, calculate the risk priority number, and finally put forward the corresponding control method.

Keywords: Expressway; Risk Identification; WBS; FMEA.

1. Introduction

Expressway is the product of national economic and social development. It is an important indicator to measure the level of urbanization and modernization of a country. Expressway projects usually have huge investment, long construction period, great technical difficulty and complex construction environment.These have greatly enhanced the uncertainty in the construction process. Therefore, it is particularly important to identify the risks of expressway projects. The existing risk identification methods are mostly applicable to the rough identification of the overall risk in the early stage of the project,but these methods lack of continuous identification in the project implementation process. Previous research methods need a lot of manpower and material resources .And the decomposition of the project may not be fine. It makes the potential risks cannot be effectively identified. Combined with WBS method, the expressway project will be decomposed to make the risk identification of the project more specific, thus effectively reduce the accident rate.

There are various risks around people, both current and potential, both internal and external, both static and dynamic, and so on. Risk identification is the first step of risk management and the basis of risk management. Only accurate risk identification of a project can ensure that correct and effective measures are taken to prevent or control risks before the implementation of the project. In the field of engineering construction, the application of risk identification is more extensive, and the requirements for risk identification are also higher.

At present, many scholars have combined WBS method to carry out research on risk identification and evaluation, which has been carried out in medicine, architecture, marine engineering and other fields. For engineering construction projects, scholars combine WBS method with different methods to realize risk identification of engineering projects. Different methods have their own characteristics, and the effects of risk identification at different stages of the project from different angles are also different.

Scholars use the method of combining Work Breakdown Structure (WBS) and Risk Breakdown Structure (RBS) for research. Guo Liqiang and Tian Yanjun added risk identification into the WBS decomposition process of the project, and conducted risk factor analysis in the decomposition process of the project work content[1]; Zhou Hongbo et al. proposed a method of risk identification based on fault tree analysis combined with Work Breakdown Structure (WBS) - Risk Breakdown Structure (RBS) to analyze the risk factors in Subway Foundation Pit Engineering[2]; Zhang Zhiqing and Wang Wenzhou proposed to improve the risk identification method based on WBS-RBS matrix, and integrated multi-level fuzzy statistical methods to achieve multi-level comprehensive statistical analysis and evaluation of risks[3]; Tian Jie used WBS method to simply identify the risk sources in the construction of expressway electromechanical engineering[4]; Yu Suping identified the safety risk factors of highway engineering construction by combining the methods of WBS and RBS, and established a multi criterion and multi-level risk factor ANP structural model[5]; Xue Yao et al. established Work Breakdown Structure-Risk Breakdown Structure (WBS-RBS) on the basis of Work Breakdown Structure method to identify risks in the whole process management of water conservancy projects[6]; Wang Jingchun et al. used WBS-RBS risk analysis method to identify the risk of highway tunnel construction process, and used the coupled operation decomposition tree and risk decomposition tree to obtain basic risk events, which were taken as sample objects of k-means clustering risk assessment model[7]; Li zongkun et al. applied WBS-RBS method to decompose the project structure and risk of the artificial island construction system of Hong Kong Zhuhai Macao Bridge, which is complex and has many uncertain factors, and constructed WBS-RBS risk identification matrix[8].

Scholars use other methods to realize risk identification of engineering projects. Jiang Huijie et al. classified the main influencing factors into hard and soft indicators and established a risk indicator system through risk identification of expressway project construction progress[9]; Dong Liuqun proposed the process and method of risk identification in the whole life cycle of expressway projects[10]; Chen Guohua et al. constructed a construction risk assessment system from three aspects of occupational health, safety and environment (HSE), comprehensively applied the Work Breakdown Structure-Risk Breakdown Structure (WBS-RBS) and analytic hierarchy process (AHP) to establish an assessment model to carry out the HSE risk assessment of cross sea bridge construction[11];Shi Zhou et al. carried out a two-dimensional decomposition of the bottom process and risk sources in the whole process of caisson foundation construction based on the method of work and risk structure decomposition to identify the risk sources[12].

Most scholars have proposed risk identification methods based on WBS-RBS method, focusing on the construction of models. This method is more comprehensive for the identification of project risks, but it lacks judgment on the severity and incidence of risks, and can not take appropriate measures to prevent risks. However, the research on risk management of Expressway Project Based on WBS method is relatively few. Based on WBS method and FMEA method, this paper takes Xiyu expressway project as an example to carry out risk identification, decomposes the work structure of expressway construction project, and identifies the risk source more specifically and clearly.

2. Research method

In this paper, the work breakdown structure (WBS) method is used to decompose the project into work packages, and then the risks in each work package are identified and evaluated by combining the failure mode and effects analysis (FMEA) method.

2.1 Work Breakdown Structure (WBS) method

Work Breakdown Structure (WBS) is a group of project elements guided by deliverables. The specific steps are project group → project → task → activity → work package → work unit[13]. WBS is very important in engineering construction projects. WBS requires that the whole work scope of the project be covered, and any stage of the project shall not be omitted, but the work unrelated to the project shall not be included. The definition of the work of the project shall be more detailed at each lower level, but the decomposition shall not be too detailed, resulting in the independence of various tasks. In engineering projects, the project is usually divided into work packages, and the lowest work package can be assigned to the specific person in charge to meet the supervision of project progress and cost. For the expressway project, the specific WBS decomposition method is shown in Figure 1.

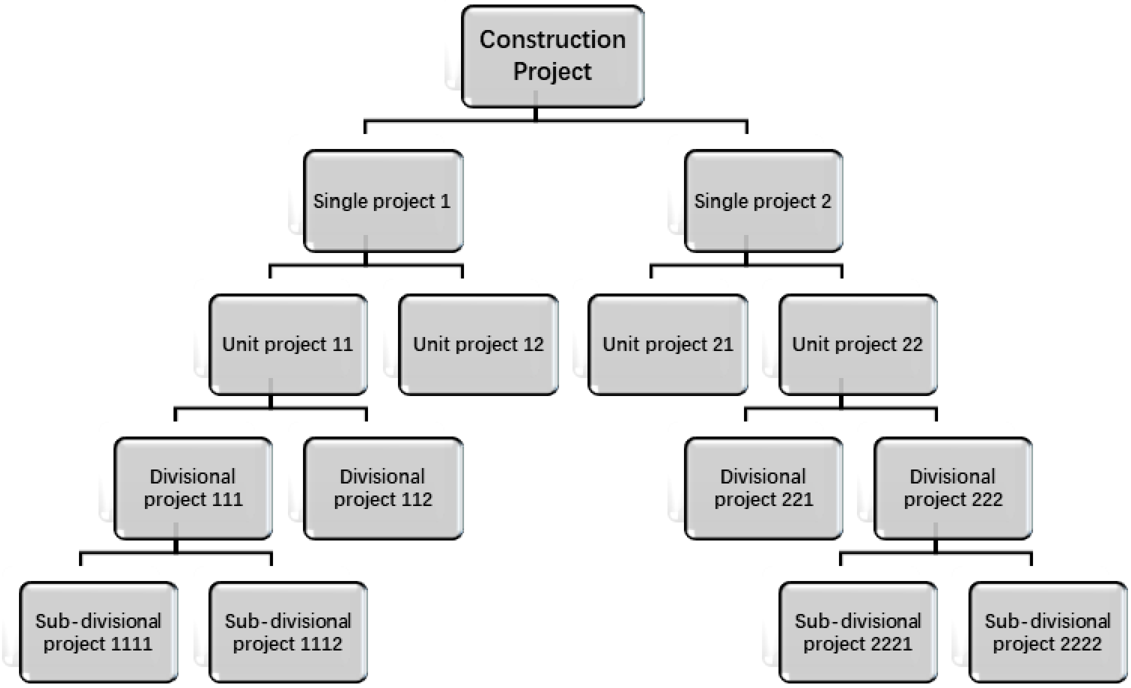

Figure 1. WBS breakdown structure

2.2 FMEA analysis method

FMEA is a set of analysis modes first formed by NASA. It is an analysis method used to determine potential failure modes and their causes and is applicable to many engineering fields. Potential risks are found before construction or mass production of products, and the criticality of different risks can be assessed through risk priority number (RPN), effective prevention can be carried out as soon as possible, and the control plan and emergency plan can be improved to ensure the smooth completion of the project. The risk priority number is composed of three parts: severity (SEV), occurrence (OCC) and detection (DET). After experts score these three factors (1-10) (See Table 1 for scoring indicators), the three data are multiplied. The greater the risk coefficient, the greater the risk of failure, which determines the priority of action[14]. Unlike the traditional brainstorming method which lists the possible risks of a project, this paper combines the WBS method, divides the project into specific work packages and identifies the potential risks by FMEA method, which can effectively avoid missing items. The specific steps are as follows:

1.List the potential failure modes corresponding to the influencing factors affecting project success during the implementation of each work package.

2. List potential failure effects corresponding to potential failure modes.
3. Experts score the severity of each impact.
4. Identify potential causes of failure.
5. Experts score the frequency of various causes.
6. Record current control methods to prevent failures or causes.
7. Experts score the detectability of the failure or cause.
8. Calculate the risk priority number.

Table 1. FMEA score index

Project Grade Score	SEV	OCC	DET
1	There is no negative impact on the customer or the impact can be ignored so that it does not attract the attention of the customer.	The chance of occurrence is small and unlikely. Usually less than one in a million.	It is very certain that this potential failure will be detected and prevented before reaching the customer. It is certain that design controls can be used to identify causes/mechanisms and failure patterns.
2	It can be detected by careful customers and may cause minor discomfort.	The probability of occurrence is very small, less than 1/100,000.	It is almost certain that this potential failure will be detected and prevented before reaching the customer, and a very high opportunity to identify its causes/mechanisms and failure patterns through design controls.
3	Approximately 50% of customers are aware of it and are uncomfortable with its slight non-main performance degradation.	The probability of occurrence is very small, less than 1/10000	This potential failure has a small chance of not being detected before reaching the customer and a high chance of discovering its cause/mechanism and failure modes through design controls.
4	Most customers are aware of this and are dissatisfied with the reduced non-main performance.	Occasionally, about 1/1000	The failure may be detected or prevented by control before reaching the customer with a medium-high chance of discovering its cause/mechanism and failure modes through design control.
5	Continuous non-main performance degradation has either caused or inconvenienced the customer's production.	The chance of occurrence is moderate, about 1/400	There is a medium chance that this failure will reach the customer undetected.
6	Repairs during the warranty period occur or customers have quality complaints during manufacturing/assembly.	Moderate chance of occurrence, about 1/80	Even with design controls, the likelihood of detecting or preventing this potential failure before reaching the customer is relatively low.
7	Customers are highly dissatisfied, one/some parts are partially disabled, and customer production is severely affected by high scrap or high rework rates.	Considerable chance of occurrence, about 1/20	It is unlikely that this potential failure will be detected before reaching the customer.
8	Customers are highly dissatisfied and the product is no longer functioning, but it does not contravene safety requirements or government regulations.	High chance of occurrence, about 1/8	It is almost impossible to detect this potential failure before reaching the customer.
9	Customers are threatened with security or will violate government regulations if this failure occurs, but customers can be warned before an accident occurs.	It almost certainly happens, about 1/3	Current controls may not detect this potential failure.
10	If a failure occurs, the customer will be threatened with security without warning or will violate government regulations as a result.	It is certain that it will happen and the incidence is not less than 50%	Current controls are totally unable to detect this potential failure.

3. Case analysis

Taking Xiyu expressway as an example, this paper uses WBS method to decompose project construction and combines FMEA method to identify risks. Because of the huge amount of the project, this paper selects one of the sections——Tuhe super major bridge for specific analysis. First, WBS method is used to decompose the Xiyu expressway project, with emphasis on the Tuhe super major bridge. Then, potential risks are identified for specific work packages and further analyzed by FMEA method.

3.1 Application of WBS method in decomposition of Xiyu Expressway Project

Xiyu expressway is an important section of the seventh horizontal line in the "3 vertical lines, 12 horizontal lines and 12 ring roads" in the "Shanxi expressway network adjustment plan". The starting point is located at the boundary of Shanxi and Hebei provinces, connected to Hengshui Xiyang Expressway planned by Hebei Province in the East, and the ending point is located in Yuci District of Jinzhong City, connected to Yuqi Expressway in the West. In this project, Tuhe super major bridge crosses Tuhe River and S318 line, and there are 4 sets of Tuhe super major bridge: 2X (3X40)+(83+155+83)+3X40m.The third section of the superstructure is a prestressed concrete continuous rigid structure, with cantilever pouring. The rest sections are prestressed concrete (post tensioned) T-beams, which are simply supported first and then continuous. The central stake number of the bridge is K111 + 009.5, and the right front included angle is 90 °. Column abutment is adopted for substructure abutment, double thin-wall hollow pier is adopted for No. 4 and No. 10 piers, column pier is adopted for other piers, and bored pile foundation is adopted for piers and abutments.

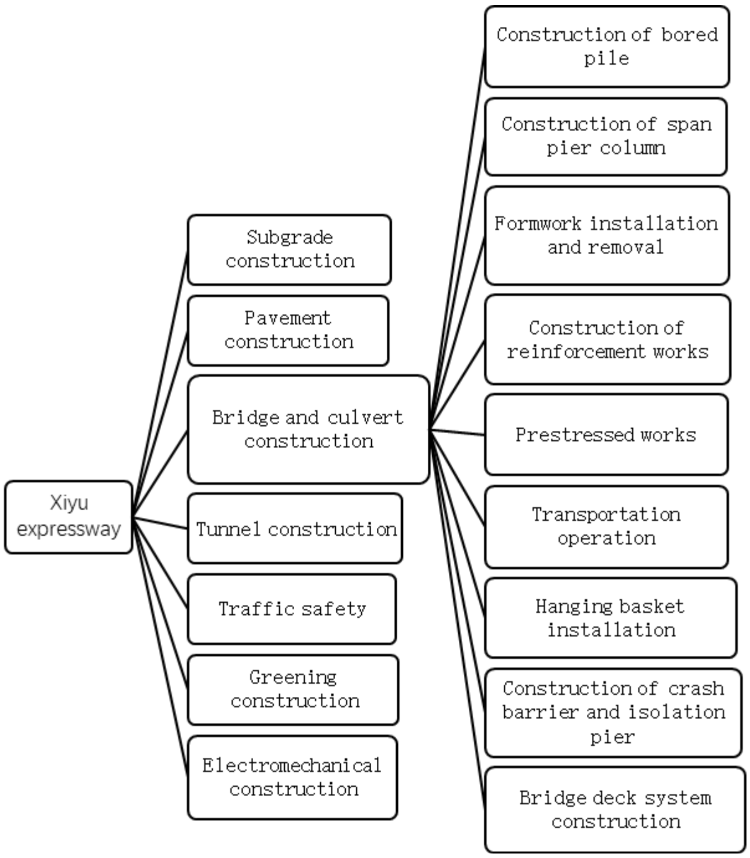

Figure 2. WBS decomposition structure of Xiyu Expressway

According to the construction sequence of Expressway and the construction characteristics of Xiyu expressway, the construction of Xiyu expressway is firstly divided into seven stages: subgrade construction, pavement construction, bridge and culvert construction, tunnel construction, traffic safety, greening construction and electromechanical construction. Among them, bridge and culvert construction refers to Tuhe super major bridge stage. The construction scheme for the upper span of Tuhe super major bridge over line S318 (K138 + 000) belongs to the special road related construction scheme. The crossing is the third bridge. The bridge span of this bridge is (83 + 155 + 83) m. It is proposed to adopt the hanging basket casting method for construction. In combination with the construction requirements of the hanging basket casting method, it is further divided into nine work packages as shown in the figure above.

3.2 Application of FMEA method in construction risk identification of Tuhe super major bridge

This study is mainly carried out from the nine work packages of the construction part of Tuhe super major bridge, namely, bored pile construction, cross pier column construction, formwork installation and removal, reinforcement engineering construction, prestressed engineering, transportation operation, hanging basket installation, crash barrier, isolation pier construction and bridge deck system construction, and analyzes their potential failure modes and potential causes in the construction process.The relevant participants of the project will score the severity, occurrence rate and detection rate. After multiplying the three scores, the risk priority number will be obtained. The risk degree will be judged by the size of the risk priority number. Those with a coefficient less than 120 are general risks, and those with a coefficient greater than 120 are major risks. Finally, the corresponding control methods will be proposed for each potential failure mode.

First of all, according to the specific construction methods and construction characteristics of the nine work packages, from the perspective of people, facilities and equipment, environment and management, this paper determines the potential failure modes corresponding to the influencing factors affecting the success of the project during the implementation of each work package as shown in the table below.

Table 2. Potential failure modes of each work package

Number	Operations Content	Potential Failure Modes
1	Bored pile Construction	Lifting injury, object strike, electric shock, mechanical injury
2	Cross pier column construction	Lifting injury, falling from height, object strike, mechanical injury
3	Formwork installation and removal	Lifting injury, object strike, falling from height, mechanical injury
4	Reinforcement engineering construction	Lifting injury, object strike, mechanical injury, electric shock, oxygen acetylene explosion
5	Prestressed engineering	Object strike and mechanical injury
6	Transportation Operation	Object strike and falling from height
7	Hanging basket installation	Instability, falling from height, object strike, mechanical injury
8	Crash barrier, isolation pier construction	Falling from height, mechanical injury, electric shock
9	Bridge deck system construction	Falling from height and mechanical injury

Next, relevant participants of the project will score the severity, occurrence and detection rate of each potential failure mode by using their professional knowledge and combining with the actual situation of the project, and then multiply the scores to obtain the risk priority number. According to the classification criteria mentioned above, potential failure modes are divided into general risks and large risks. The results are shown in the table below.

Table 3. FMEA risk scoring table

Number	Operations Content	Potential Failure Modes	SEV	OCC	DET	RPN	Risk Level
1	Bored pile Construction	Lifting injury	3	3	2	18	General risk
		Object strike	2	2	2	8	General risk
		Electric shock	3	3	3	27	General risk
		Mechanical injury	5	6	6	180	Large risk
2	Cross pier column construction	Lifting injury	6	6	6	216	Large risk
		Falling from height	6	6	6	216	Large risk
		Object strike	6	6	6	216	Large risk
		Mechanical injury	5	5	6	150	Large risk
3	Formwork installation and removal	Lifting injury	3	2	2	12	General risk
		Object strike	5	6	6	180	Large risk
		Falling from height	7	8	8	448	Large risk
		Mechanical injury	2	3	3	18	General risk
4	Reinforcement engineering construction	Lifting injury	3	2	2	12	General risk
		Object strike	6	6	6	216	Large risk
		Mechanical injury	7	7	7	343	Large risk
		Electric shock	5	5	5	125	Large risk
		Oxygen acetylene explosion	5	5	5	125	Large risk
5	Prestressed engineering	Object strike	3	3	3	27	General risk
		Mechanical injury	6	5	5	150	Large risk
6	Transportation Operation	Instability	7	6	6	252	Large risk
		Lifting injury	3	5	5	75	General risk
		Object strike	7	8	8	448	Large risk
		Falling from height	7	7	7	343	Large risk
7	Hanging basket installation	Instability	6	7	6	252	Large risk
		Falling from height	7	6	7	294	Large risk
		Object strike	3	4	4	48	General risk
		Mechanical injury	2	2	2	8	General risk
8	Crash barrier, isolation pier construction	Falling from height	7	6	6	252	Large risk
		Mechanical injury	4	3	3	36	General risk
		Electric shock	3	3	3	27	General risk
9	Bridge deck system construction	Falling from height	3	2	3	18	General risk
		Mechanical injury	2	2	2	8	General risk

It can be seen from the above table that there may be the same potential failure modes when different work packages are carried out, but based on the different characteristics of the work content, their index scores are different and their risk priority numbers are not the same. For these potential failure modes, this paper records the current control methods to prevent failure. The control methods for lifting injuries and mechanical injuries that may exist in different operations are the same.For the object strike risk, except for the different control methods during the construction of bored piles, the control methods during the construction of other operations are the same. Specific control methods are as follows:

When carrying out bored pile construction, cross pier column construction, formwork installation and removal, and reinforcement engineering construction, lifting injuries may be caused due to factors such as people, facilities and equipment, and management. The control methods are as follows: 1.Select the focus point in combination with the distribution of the component center of gravity; 2.The components can be hoisted only after they are bound stably.

During the construction of span pier column, formwork installation and removal, reinforcement engineering construction, prestressed engineering, hanging basket installation method, crash barrier and isolation pier construction and bridge deck system construction, mechanical injury may be caused due to human, facility equipment and management factors. The control methods are as follows: 1. Strictly follow the operating regulations of mechanical equipment; 2. Regular maintenance and inspection of machinery; 3. There shall be no personnel in the operation radius.

During the construction of span pier column, formwork installation and removal, reinforcement engineering construction, prestressed engineering, transportation and hanging basket installation, objects may strike due to human and environmental factors. The control methods include: 1. Mechanical equipment shall be constructed within the specified operation range; 2. Objects to be hoisted at height shall be bound firmly according to regulations and commanded by specially assigned personnel; 3.wear necessary safety labor protection articles; 4. Set up a safe working platform.

During the construction of bored cast-in-place piles, objects may be struck due to human and equipment factors, which is a general risk. The control methods are as follows: 1. Chute shall be set up, and wastes shall not be thrown down at will; 2. Scaffold and other operation platforms shall be erected. Electric shock may be caused by human and management factors, which is a general risk. The control method is that the electrician should regularly check the wires and lines, and replace and repair the wires in time in case of wire damage, equipment leakage and other phenomena.

During the construction of span pier column, falling from height may be caused due to human, equipment and management factors, which is a major risk. The control methods are as follows: 1. Operators shall wear safety belts and anti-skid shoes, and it is forbidden to work up and down at the same time; 2. Set up safe passage.

During formwork installation and removal, falling from height may be caused due to human and environmental factors, which is a relatively high risk. The control methods are as follows: 1. Operators shall wear safety belts and anti-skid shoes. It is forbidden to work up and down at the same time; 2. Displacement observation piles shall be set.

During the construction of reinforcement works, electric shock may be caused by factors such as people, facilities and equipment. The control method is that electricians should regularly check wires and lines, and replace and repair wires in time in case of wire damage, equipment leakage and other phenomena. Oxygen acetylene explosion may be caused by factors such as people, facilities and equipment, which is a relatively high risk. The control methods include: 1. Operate in strict accordance with the operating procedures; 2. Store the tank according to the specifications.

During transportation, instability may be caused by human and environmental factors, which is a large risk. The control methods include: 1. Scaffold erection shall be carried out in strict accordance with the scheme; 2. The foundation shall be treated to meet the requirements of the scheme. Lifting injury may be caused by factors such as people, facilities and equipment, which is a general risk. The control method is the same as above. Falling from height may be caused by factors such as people, facilities, equipment and management, which is a relatively high risk. The control methods include: 1. Set up special ladders; 2. Staff shall wear safety articles.

When the hanging basket installation is carried out, instability may be caused due to human and management factors, which is a large risk. The control methods include: 1. Select the focus in combination with the distribution of the center of gravity of the components; 2. The components can be hoisted only after they are bound stably. Due to factors such as people, facilities and equipment, falling from height may be a relatively high risk. The control methods are as follows: 1. Operators shall evacuate the pier in time before being in place; 2. A special ladder is set on the top.

During the construction of anti-collision barrier and isolation pier, falling from height may be caused due to factors such as personnel, facilities and equipment management, which is a relatively high risk. The control methods are as follows: 1. Chute should be set up, and wastes are strictly prohibited from being thrown downward at will; 2. Scaffold and other operation platforms shall be erected. Electric shock may be caused by human and management factors, which is a general risk. The control method is the same as above.

During the construction of bridge deck system, falling from height may be caused due to factors such as personnel, facilities and equipment management, which is a general risk. The control methods are as follows: 1. Do a good job in safety enclosure and protection; 2 wear the safety belt correctly; 3. Set up a safe working platform.

4. Conclusions

For the Tuhe super major bridge section of Xiyu expressway, it is decomposed into nine work packages by WBS method, and potential risk sources are analyzed by FMEA method. The severity, occurrence and detection rate of risk are scored, and large or general risks are identified. The corresponding control methods are put forward for different risks, and the full identification of bridge construction stage risks in highway is achieved. This method can also be used to identify risks in other construction links or other engineering projects of highway projects, and accurately control the safety and quality of project construction.

In addition, there is some degree of similarity and duplication in identifying the risk sources under different work packages during the research process, but this method lacks an integrated summary of this part, which can reduce the workload to a certain extent and improve the overall management of the project.

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