The Security Risk Evaluation of Railway Construction Based on CIM Model

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Abstract. In this paper, the CIM model is used to evaluate and manage the safety risk of subway construction. Taking Nanchang Metro Line 4 bid section 3 as an example, the total safety risk of the project construction is estimated, and the corresponding countermeasures are proposed, which is of certain significance to avoid and respond to the construction project risk. The results show that the possibility of moderate total safety risk in the construction of the third bid section of Nanchang Metro Line 4 is relatively large, and the probability is about 40%.

1. Introduction
In recent years, various types of accidents such as surface subsidence, underground pipeline destruction and cave-in collapse have occurred in the construction of Nanchang metro. Therefore, the safety awareness is not strong in the construction of the subway, and the influence of the surrounding environment and the structure of the construction site are not well controlled. Therefore, it is very necessary to accurately evaluate and manage the construction risk, control, curb the occurrence of accidents, especially major safety accidents, and strengthen the safety risk management of subway construction. The safety risk management of subway construction is an important guarantee for the safety construction of subway engineering and the completion of quality as scheduled, which is of great significance for the construction of subway project.

2. CIM model in subway construction safety risk assessment.

2.1. CIM model
The CIM model is divided into "parallel response model" and "series response mode". It is assumed that there are n risk factors in activity P. if any risk occurs, it will affect the activity P, then the risk factor R1, … In 2005, the probability distribution combination of Rn is called "parallel response model". In the whole risk of the construction of the subway, the risk factors at all levels are random, and the risk factors at the same level can be simplified into and connected with the cross-correlation system, and the "parallel-response mode" of the CIM model type can be used.

2.2. Assessment steps
Because it is difficult to directly quantify the construction safety risk factors of subway engineering, the weight of the evaluation index is determined by the analytic hierarchy process (AHP), and the probability distribution of the lowest risk factors is determined by fuzzy evaluation. The construction safety risk assessment steps of subway project are shown in figure 1.
Fig. 1 steps of subway construction safety risk assessment based on CIM model

The project team invites each expert to give an evaluation $j$ of the lowest risk factor $i$ for the subway project. The evaluation set is: $V = \{\text{the risk is high, the risk is high, the risk is moderate, the risk is low, the risk is low}\}$. The probability distribution $P_{ij}$ for each of the lowest risk factors is calculated as follows:

$$P_{ij} = \frac{N_j}{N}$$

(1)

In the formula, $N_j$ is the number of experts who evaluate the risk factor $I$ is the same risk level $j$, and $N$ is the total number of experts.

Finally, according to the probability distribution analysis, the level and probability of the security risk of the project team are obtained.

3. Application of CIM model to determine the total safety risk of construction in 3 section of Nanchang Metro Line 4

3.1. Overview of Section 3 of Nanchang Metro Line 4
The scope of this bid section includes Minyuan Road station and the section between Minyuan Road station and Qingshanhu west station.

The project scope of this section includes Minyuan Road Station and Station-Qingshan lake Station interval. Minyuan Road Station is an intermediate station of Nanchang Metro Line 4. The station is located directly below the ten-character intersection of Coking West Road and Wanghua Road planned in Chaoyang District, and is set up in the east-west direction. The construction of 841 station of this car is carried out in two stages. According to the current demolition and drawing situation, it is planned to construct the first phase of the station and shield shaft, and the construction of the second stage of the station will not be carried out until the demolition is completed.

The first phase of the station is located directly below the ten-character intersection of Technology Road and Minyuan Road planned in Chaoyang District, which is set up in the east-west direction. The total length of the first phase is 175.35 m. The north side is the land reserve center, and the Southeast side is the supporting residential land under construction.

3.2. Safety evaluation system for subway construction
According to the actual engineering situation of No. 3 section of Nanchang Metro Line 4, the construction safety evaluation system of the section is determined as shown in Fig. 2.
3.3. Determination of the weight of risk factors

The analytic hierarchy process (AHP) is used to determine the weight of risk factors. According to the actual situation of 3 section of Nanchang Metro Line 4, figure 2 is used as the hierarchical diagram of risk factors. The weight of the C1-C10 risk factors is determined by the analytic hierarchy process (see Table 1). For sub-risk factors of each D layer below the C level, the weight is determined to be the same.

![Construction safety evaluation system of a section of Nanchang Metro Line 4](image)

**Table 1 C Level Risk Factor Weight**

| C Level | B1(0.055) | B2(0.290) | B3(0.655) | W  |
|---------|-----------|-----------|-----------|----|
| C1      | 0.200     | 0.000     | 0.000     | 0.011 |
| C2      | 0.800     | 0.000     | 0.000     | 0.044 |
| C3      | 0.000     | 0.264     | 0.000     | 0.077 |
| C4      | 0.000     | 0.124     | 0.000     | 0.036 |
| C5      | 0.000     | 0.511     | 0.000     | 0.148 |
| C6      | 0.000     | 0.069     | 0.000     | 0.020 |
| C7      | 0.000     | 0.032     | 0.000     | 0.009 |
| C8      | 0.000     | 0.000     | 0.671     | 0.440 |
| C9      | 0.000     | 0.000     | 0.073     | 0.048 |
| C10     | 0.000     | 0.000     | 0.256     | 0.168 |
3.4. Construction safety risk assessment

3.4.1. Calculation of the probability distribution of sub-risk factors
Ten experts evaluated the 3 section of Nanchang Metro Line 4 and determined the risk grade of the lowest risk factors of the section. According to the expert's evaluation \( j \) of ultimate risk factor \( i \), the probability distribution of each risk factor is calculated by \( P_{ij} \), as shown in Table 2.

| Risk factor | Top | Bottom | Left | Right | Gutter |
|-------------|-----|--------|------|-------|--------|
| C1          | 0.4 | 0.3    | 0.3  | 0.0   | 0.0    |
| C2          | 0.4 | 0.5    | 0.1  | 0.0   | 0.0    |
| C3          | 0.2 | 0.2    | 0.5  | 0.1   | 0.0    |
| C4          | 0.6 | 0.4    | 0.0  | 0.0   | 0.0    |
| C5          | 0.3 | 0.5    | 0.2  | 0.0   | 0.0    |
| C6          | 0.6 | 0.4    | 0.0  | 0.0   | 0.0    |
| C7          | 0.2 | 0.2    | 0.3  | 0.2   | 0.1    |
| D1          | 0.2 | 0.3    | 0.3  | 0.2   | 0.0    |
| D2          | 0.1 | 0.2    | 0.3  | 0.3   | 0.1    |
| D3          | 0.2 | 0.3    | 0.4  | 0.1   | 0.0    |
| D4          | 0.3 | 0.4    | 0.2  | 0.1   | 0.0    |
| D5          | 0.1 | 0.3    | 0.4  | 0.1   | 0.1    |
| D6          | 0.4 | 0.6    | 0.0  | 0.0   | 0.0    |
| D7          | 0.2 | 0.4    | 0.4  | 0.0   | 0.0    |
| D8          | 0.1 | 0.5    | 0.3  | 0.1   | 0.0    |

3.4.2. Calculation of the probability distribution of C-level risk factors
Because C8, C9, C10 have the same weight, the probability distribution of C8, C9 and C10 is calculated by parallel response model, as shown in Table 3.

| Risk factor | Level of risk |
|-------------|---------------|
|             | Top | Bottom | Left | Right | Gutter |
| C8          | 0.02 | 0.34  | 0.54 | 0.1   | 0.0    |
| C9          | 0.012 | 0.268 | 0.44 | 0.18  | 0.1    |
| C10         | 0.004 | 0.071 | 0.357 | 0.468 | 0.1    |

3.4.3. calculate the probability distribution of level B risk factors.
Combined with the weight of risk factors shown in Table 1, the probability distribution of level B risk factors is calculated.

| Risk factor | Level of risk |
|-------------|---------------|
|             | Top | Bottom | Left | Right | Gutter |
| C1          | 0.4000 | 0.4600 | 0.1400 | 0.0000 | 0.0000 |
| C2          | 0.3283 | 0.3919 | 0.2438 | 0.0328 | 0.0032 |
| C3          | 0.0153 | 0.2659 | 0.4859 | 0.2001 | 0.0329 |

3.5. Construction safety risk management of 3 section of Nanchang Metro Line 4
According to the risk assessment in the construction stage, it can be seen that there are 7 risk projects, 6 secondary projects, 11 second grade risk projects, 2 grade 1 and 1 special grade in the construction risk of 3 section of Nanchang Metro Line 4.
The construction stage is divided into the construction preparation stage, the construction stage and the end of the work period for the safety risk management engineer which is convenient to carry out the construction phase effectively.

3.5.1. Construction preparation phase
1) It is necessary to establish an effective management organization and define its management responsibilities.
2) Combined with the detailed survey report of geotechnical engineering, the engineering geology and hydrogeology within the engineering influence range are surveyed, and the environmental conditions of buildings and underground pipelines in the engineering influence area are comprehensively verified with the environmental investigation report and design documents.
3) Optimization design scheme
   According to the scheme optimization, the selected scheme is further refined and optimized, so that the possibility of the design scheme to the construction risk is ensured to be the lowest.

3.5.2. Construction phase
1) In the construction stage, it is necessary to make the construction process informative. The construction unit and the supervision unit and the third party monitoring unit shall strengthen the management of the safety risk technical operation and strengthen the information submission, and organize the analysis and the wind risk disposal in time for the early-warning state.
2) In the process of construction, we should pay attention to the change of construction environment in time, and the item department should organize geological survey, engineering structure inspection and surrounding environment verification.
3) In view of the environmental safety risk in the safety risk grade, we must pay attention to the influence of subway construction on the surrounding buildings in the construction process.
4) In the construction process, we should pay attention to the safety risk caused by precipitation, especially when the project involves excavation of foundation pit, a large amount of precipitation can cause instability of foundation pit.

3.5.3. Post-construction phase of the project
1) After the construction is completed and the surrounding environment is deformed and stable, the assessment shall be carried out to provide the necessary measures for the rehabilitation of the environment.
2) When the post-work assessment considers that the risk project has environmental safety risk or engineering hidden danger, it should be repaired according to the restoration and planning advice of the qualified and experienced design unit.

4. Conclusion
In this paper, the CIM model is used to analyze the 3 section of Nanchang Metro Line 4 as an example, and it is considered that the possibility of moderate total safety risk in engineering construction is 40%. This paper briefly discusses the risk analysis and countermeasures in the construction project, which is of certain significance to avoid and deal with the risk of the construction project.

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References
[1] Ding Zhenming. Discussion on the management of the safety monitoring system of the existing structures through the underground engineering. Municipal Technology,2009,27 (S2):361-363.
[2] Zhou Limin. The development strategy of urban rail transit in China[J]. Urban Rail Transit,2002,24 (10):34-37.
[3] Qu Zhenyan. The application of safety risk management system in subway construction[J]. Railway Construction Technology,2011 (S2):197-199.
[4] Qihao. subway station construction Set up risk analysis and countermeasure[J]. Urban Rail Transit,2012 (8):94-98.
[5] Cui Jiujiang. The construction risk of shield tunnel and the countermeasures[J]. Urban Express,2009 (4):377-396.