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Risk Management of Urban Pipe Gallery Based on System Dynamics

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Abstract. Under the background of continuous urbanization in China, urban underground comprehensive pipe gallery will become an inevitable trend of urban comprehensive management in the future. After the completion of the management gallery, how to effectively manage the risks in operation and maintenance management has become a topic at this stage. Based on the classic method of AHP combined with DSM method, and through a lot of literature research, to build the relationship between the risk of an integrated pipe rack system, and has carried on the system dynamics simulation using Anylogic software, finally, the simulation results obtained a few of comprehensive pipe gallery has the greatest effect in the overall risk of several risk paths, convenient operational phase in the pipe gallery risk in the future, you can draw on the results of several path for more effective management.

1. Literature Review

Driven by the encouragement of national policies and the upgrading of urban management, China's urban underground utility corridors have been built or put into operation in 167 cities in 31 provinces, autonomous regions and municipalities directly under the Central Government. However, although thousands of kilometers of pipe corridors have been built, how to effectively manage and maintain them remains a problem.

1.1. Background

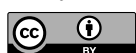
After put into operation in large quantities of pipe rack, however, especially in Beijing that adopt decentralized management model, under the condition of each operational company responsible for the company of the utility tunnel area management alone, but when the pipe rack size increasing, the competent department of difficult to comprehensive macro grasp of municipal utility tunnel operating conditions, risk problem will appear in the following several aspects.

- 1) Difficult management of security risks.
- 2) The emergency plan system is not perfect.
- 3) Heavy pressure in operation and maintenance supervision.

However, the decentralized management of the comprehensive management gallery in Beijing is unlikely to change before the unified coordination of relevant parts. Therefore, it is necessary to study a scientific risk response measures for the ineffective risk supervision in the above three aspects.

1.2. The Research Status

In terms of the risk research on the operation and maintenance risks of comprehensive management corridors, Li Qian et al. comprehensively analyzed the risk factors in the operation and maintenance management of comprehensive management corridors in China by means of literature analysis, causal analysis and expert investigation. DEMATEL method was used to rank the degree of influence and



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importance of 22 identified risk factors [1]. Duan Muxiangling et al judged the fire risk of comprehensive pipe gallery based on the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method (FCEM), and established the fire risk evaluation model of comprehensive pipe gallery [2]. Wang Shuhong et al. established the coupling degree model by using the fuzzy mathematical method to obtain the coupling relation between multiple disaster species, and finally proposed the risk assessment method for the combined pipe gallery caused by multiple disaster coupling [3]. In terms of risk analysis and judgment, Franck Marie proposed a decision support system (DSS) for project risk and risk interaction modeling and management to facilitate project managers to make decisions on risk countermeasures [4]. In terms of the simulation of risk accidents, Lu Qiuqin built the system dynamics model. The logistics warehouse of Ningxia Hongde Logistics Packaging Co., Ltd. is selected to carry out operation analysis and verification of the model. The results show that increasing the safety input or changing the safety input ratio of subsystems can improve the safety level of warehouse fire accident.

2. Risk Path

In this paper, according to the relevant laws and regulations on the operation and maintenance of the integrated management corridor, the relevant operation and maintenance management requirements documents and the previous literature on the risk research in the operation and maintenance of the integrated management corridor, the risk factor table of the integrated management corridor is obtained.[6] The risk factors are classified according to the grade. However, the obtained risk factor results were communicated with the comprehensive management gallery operation and maintenance experts, and finally, after modification, induction and sorting, etc., the following 5 types of category I risks were concluded, which were denoted as R_i , and 20 types II risks were denoted as R_{ii} , as well as the relevant basis for the conclusion.

2.1. Pipe Gallery Safety Risk Factors

Before studying the risk management of integrated corridors, it is important to first identify the types of risk factors that have an impact on the integrated safety of corridors. Risk factors refer to any event that increases the frequency or severity of risk accidents.

Table 1. Higher frequency risk factors

Primary risk	The secondary risk	Primary risk	The secondary risk
Manage team risk	Team informatization level Member level Safety awareness level Information management level Psychological state of person	Pipeline risk	Pipeline leak Untimely maintenance Pipeline deviation, sliding down Pipe explosion, fire
Environmental risk	Disaster influence The illegal invasion The construction destruction Temperature and humidity Chemical gas concentration	Risk of ancillary facilities Pipe gallery ontology risk	Lighting, ventilation facilities Information is not connected Risk induction facility Design and construction problems Construction problems Unreasonable design Information transfer

Due to the pipe rack less research of operational risk, the risk factors for the pipe gallery summary is also less reference sample, so begin from two types of literature, this paper study the comprehensive utility tunnel risk class of literature and a variety of large-scale projects operational risk management

literature, extract frequency higher level of risk factors, and the secondary risk factors. The risk factors with higher frequency are shown in Table 1.

2.2. Risk System Path Determination

In determining the comprehensive utility tunnel after all kinds of risk factors in the process of operations, then according to the aforementioned improved analytic hierarchy process (AHP) [7] to deal with each risk factor, obtain the real risk factors were weighted, then according to these weights to build risk structure matrix (DSM)[8] interactive relations between all the factors, in preparation for the next using the established model.

If we want to determine the potential relationship between the five first-level risks and 20 second-level risks and the corresponding path weight, we should analyze the relationship between each first-level risk and the comprehensive risk of the pipe gallery from three aspects. The relationship between each first-level risk and its corresponding second-level risk; And the potential relationship between secondary risks. This part is divided into three steps. Here, the calculation of risk relationship matrix of each level of risk and the comprehensive risk of the pipe gallery is taken as an example. The judgment matrix is based on the interview of relevant experts and their comprehensive score, which is divided into five levels.

The experts were interviewed in the form of online questionnaire, and the data of the answers were processed by the experts, so as to obtain the judgment matrix of the risks of each first-level risk and the comprehensive risk of the management gallery as follows. Then, the judgment matrix is calculated. The principle of calculation is described above. Here, R language is used to program the entire hierarchical analysis algorithm.

2.3. Pipe Gallery Safety Risk Factors

Using the same method as above, the weight vector between each secondary risk and its corresponding primary risk, its judgment matrix, weight vector and consistency test can be obtained. The results are shown in Table 2.

Table 2. Risk weight matrix

Type of risk	Shortcuts	Styles	Shortcuts
R1	$\begin{pmatrix} & r1 & r2 & r3 & r4 & r5 \\ r1 & 1 & 1 & 3 & 2 & 5 \\ r2 & 1 & 1 & 2 & 0.3 & 4 \\ r3 & 0.3 & 0.5 & 1 & 0.5 & 2 \\ r4 & 0.5 & 3 & 2 & 1 & 3 \\ r5 & 0.2 & 0.25 & 0.5 & 0.3 & 1 \end{pmatrix}$	(0.342 0.206 0.118 0.269 0.065)	0.057 0.051
R2	$\begin{pmatrix} & r6 & r7 & r8 & r9 \\ r6 & 1 & 5 & 3 & 3 \\ r7 & 0.2 & 1 & 0.5 & 0.3 \\ r8 & 0.3 & 2 & 1 & 1 \\ r9 & 0.3 & 3 & 1 & 1 \end{pmatrix}$	(0.533 0.086 0.181 0.200)	-0.011 -0.012
R3	$\begin{pmatrix} & r10 & r11 & r12 & r13 \\ r10 & 1 & 3 & 4 & 0.5 \\ r11 & 0.3 & 1 & 0.3 & 0.2 \\ r12 & 0.25 & 3 & 1 & 0.3 \\ r13 & 2 & 5 & 3 & 1 \end{pmatrix}$	(0.316 0.074 0.139 0.472)	0.043 0.048
R4	$\begin{pmatrix} & r14 & r15 & r16 \\ r14 & 1 & 0.2 & 0.3 \\ r15 & 5 & 1 & 2 \\ r16 & 3 & 0.5 & 1 \end{pmatrix}$	(0.106 0.584 0.310)	-0.014 -0.024
R5	$\begin{pmatrix} & r17 & r18 & r19 & r20 \\ r17 & 1 & 0.5 & 1 & 3 \\ r18 & 2 & 1 & 1 & 2 \\ r19 & 1 & 1 & 1 & 2 \\ r20 & 0.3 & 0.5 & 0.5 & 1 \end{pmatrix}$	(0.261 0.334 0.281 0.124)	0.033 0.037

According to the results obtained, except the judgment matrix of R2 and R5, all the other judgment matrices passed the consistency test. Through analysis to recognize, R2 environmental risk factors affected by the expert subjective judgment of error: and R5 is pipe gallery ontology risk, ask the experts is mainly engaged in the work of the comprehensive utility tunnel operations management personnel, and for these operations, risk is more related to pipe gallery ontology is about the related problems of the construction of the utility tunnel civil, so this is not what they are good at. Therefore, in view of R2, the judgment matrix was re-obtained by asking several experts and comprehensively scoring based on the opinions of many people. For R5, the judgment matrix was obtained again by asking the relevant experts engaged in the construction of comprehensive pipe gallery.

The result of the consistency test shows that the judgment matrix obtained after the improvement has passed the consistency test successfully, so it is considered that the optimization work is successful. After determining the weights between the risks of different orders, the next step is to identify the correlation paths between the secondary risks and their path coefficients. Confirmation path and path coefficient method and presented in this paper, the method is consistent, is through interviews with experts, to determine the path of risk 0, 1 structure matrix, and then according to the method described in before and the calculation method of 20 secondary risk path coefficient is obtained, finally get the relative path and the path coefficient.

3. Risk Model

3.1. Establishment of Dynamic Model

System dynamics[9-12] is a combination of qualitative and quantitative, through the construction of a physical environment close to the real situation, to determine the relationship between each quantity,

and then through computer data simulation, so as to obtain the simulation of real scene data for system description.

To establish the system dynamics model, the causal loop diagram of each factor should be determined first. In this paper, the loop diagram is constructed specifically for the pipe gallery comprehensive risk R , first-level risk R_i and second-level risk R_i , and the construction process is divided into three steps in total.

1) Determine the causal loop between comprehensive risk and primary risk. Specifically, all primary risks are linked to comprehensive risks.

2) Determine the causal loop between the primary risk and the secondary risk. Specifically, secondary risks under all primary risks are connected with corresponding primary risks.

3) Determine the causal loop between secondary risks. Specifically, the link is made according to the risk potential relationship path obtained through analysis in the previous chapter.

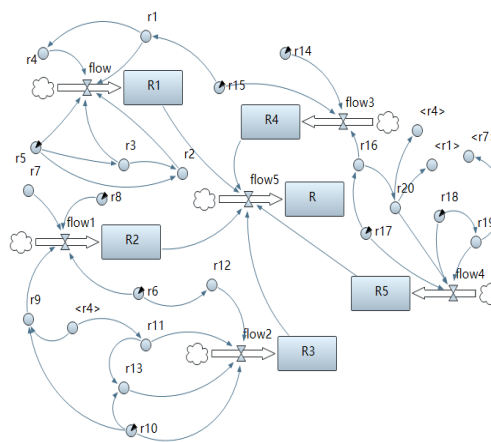


Figure 1. Risk dynamics model diagram of pipe gallery.

After more than three steps to connect various risks one by one to get the pipe gallery causal loop diagram of comprehensive risk, because the space reasons, the causal loop diagram is not drawn, built directly stock flow diagram, steps and construct the causal logic diagram method steps before, just at the time of construct stock flow diagram needs to be in the previous chapter come out through the analysis of the risk structure matrix of each risk weighting matrix for each risk and risk between the path for the assignment. In this paper, Anylogic software is used to establish the simulation model, and the resulting inventory flow diagram of integrated pipe gallery risk is shown in Figure 1.

3.2. Analysis of Results

According to the previous chapter, through the theoretical analysis to build the integrated pipe gallery risk simulation model chart, it can be seen on the model of limited range border, the whole system consists of r_5 , r_6 , the r_8 and r_{10} , r_{14} , r_{15} , r_{17} , r_{18} constitute a total of eight parameters, the rest of the risk is a dynamic variable exists in the system, and can be understood as the rest of the risk factor is the degree of risk on the basis of the eight, all kinds of paths through the model the empowerment iteration, to form the complete system. Therefore, according to the comprehensive pipe gallery risk system constructed in this paper, sensitivity analysis and testing can be conducted for the eight parameters constituting the system, so as to determine the degree of influence of these basic risks on the risk of the whole pipe gallery. In this paper, Anylogic software is still used. After the complete system stock flow diagram is constructed, the sensitivity analysis of several parameters is carried out directly on the basis of the complete model by changing the variable parameters at the same step size. Assume that the basic parameter of each parameter is 1, and the step size of sensitivity analysis is 1, increasing one step at a time. The figure of sensitivity analysis results for the eight variables obtained due to length is shown in Appendix 3. By sorting out the results of sensitivity analysis of several

variables, the line graph of sensitivity of eight variables to the overall comprehensive risk R of pipe gallery increased twice in turn was obtained, as shown in Figure 2.

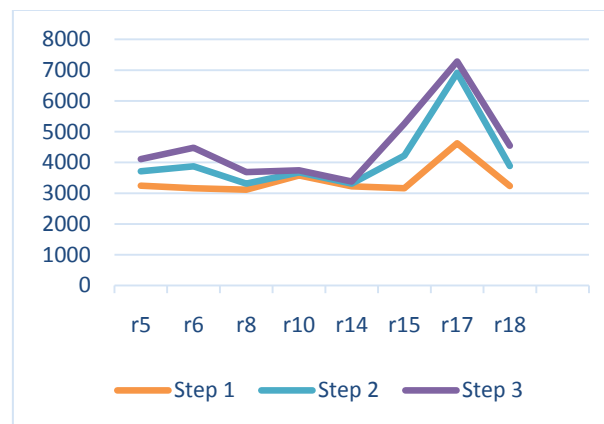


Figure 2. Sensitivity of the gallery to comprehensive risk.

According to the sensitivity analysis, after two changes of step size, r15 had the highest rate of change of comprehensive risk for pipe gallery, reaching 66.1%; R10 and R14 had the least significant rate of change, both of which were 0.05%; and the remaining risks had rates of change of R-26.5% respectively. R6 - 41.7%; The r8-18.3%; R17 - 57.4%; R18 - 40.5%. Because this article attempts through simulation method to build model, a comprehensive risk analysis of pipe gallery operations is intended to explore the influence on the overall risk of comprehensive pipe gallery's biggest risk factors, or a whole impact routes, so now to the sensitivity of the highest risk r15 underground information linkage as the main research object, analysis the secondary risk r15 for R1 - R5 five the influence degree of the level of risk. The influence results obtained through simulation are shown in Figure 3.

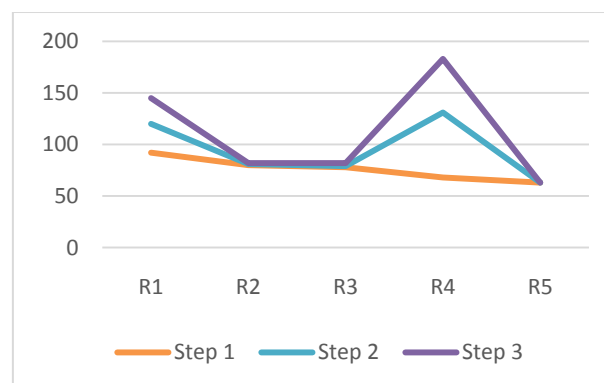


Figure 3. The degree of influence of R15 on r1-R5 level risks

4. Authors' Contributions

Beijing and even in the whole country, under such a dominant background of digital information, it has become an inevitable trend to realize comprehensive urban management corridor. In the future, how to carry out effective risk management and how to forecast and respond efficiently to risks in advance after the construction of comprehensive pipe corridors in these cities has become a necessary research work at present. In this paper, various typical risk factors of the integrated pipe gallery are analyzed, and the previous research in this field is integrated, and a mathematical analysis combined with simulation modeling method is applied to analyze the risk of pipe gallery. The main research results of this paper are as follows:

1) Based on the literature analysis method, including comprehensive utility tunnel operational risk and project risk management in the field of two frequency statistics and analysis, the article summarizes the contains five primary risks and 20 secondary risk, a comprehensive risk list of pipe gallery operations management can be used for comprehensive utility tunnel after the study of operational risk management as the basis, provide a convenient when sorting based on risk factors.

2) This paper applied a method based on analytic hierarchy process (ahp) and risk matrix method, through mathematical analysis and pushed to get a set of each risk according to risk list before the empowerment of, and according to the risk matrix to determine the risk of path between each risk, thus draw the risk between the causal loop diagram, in clearly clarify the potential relationship between each risk at the same time, for the following in simulation software to build risk stock flow chart of simulation as a preparation.

3) In this paper, through the way of combining a variety of methods, establish a system dynamics model of the risk of a comprehensive utility tunnel, and the model, the simulation experiment through the multiple parameter sensitivity analysis, thus it is concluded that the key risk factors, as well as a few seriously affect the overall risk level of risk paths, for future comprehensive pipe gallery day-to-day operational management provides relevant basis for risk response processing.

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