

Risk Management Software TRM 1.0 for Shield Tunnelling Projects

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ABSTRACT: The research work of risk management software (TRM1.0) for shield tunnelling was presented in this paper. And the context of risk management was discussed through the flowchart of risk management of shield tunnelling projects. The software TRM1.0 was designed and programmed by the integrated flow of risk management, including risk identification, risk assessment, risk evaluation, risk decision and risk monitoring based on a risk database. The method of risk assessment used in the software is expert investigation method and CIM (Controlled Interval and Memory Models) model. The risk management of shield tunnelling work can only gain by implementing TRM 1.0 more systematically than before which is a risk based approaches.

1 INTRODUCTION

Because of the uncertainty of the geologic environment and the complexity of the construction technique, a great deal of risks will be faced during the construction process of tunnelling projects. How to define, identify, assess and manage these risks becomes a big problem for the engineers and managers to resolve. So the risk management theory of large project has been developed quickly in recent years. With the development and application of risk management in tunnelling, it showed that it had much effective improvement in reducing the cost, decreasing the injuries or hazards, and so on.

Besides the uncertainties of risk itself, considerable uncertainties also exist during the risk assessment because of the information shortage. So the experience and data of the project and the similar projects before are much valuable for risk management of tunnel project. One of the philosophies behind project risk management is that the information which is generated through its use is applied in a newly tunnelling project. To allow this, risk management software with a database is generally used as a mean of analyzing, recording and documenting the information generated through the use of risk management. This method also was mentioned in Guidelines for tunnelling risk management printed by International Tunnelling Association (ITA) in 2002.

The software of risk management is of extreme importance, as not only can information store gained through the process of risk management be shared with others, it also provides the means of analyzing and calculating based on their historical data for a tunnelling project. Williams states that "the risk register has two main roles. The first is that of a repository of a corpus of knowledge..... the second role of the risk register is to initiate the analysis and plans that flow from it." On the other hand, risk management which generally includes risk identifications, risk analysis, risk evaluation, risk decision and risk monitoring, is a complex system. So with the purpose of storing the valuable information and simplifying the process, the development of risk management software has become an important research topic recently. A lot of scholars have done many valuable research works in this field and some commercial software systems have been applied and accepted by the engineers.

The existing risk management software can be divided into two types, namely risk register database system and risk assessment system. For risk register database system, Williams, Carter et al. and Ward gave some examples of the type of information or items which can be stored in the 'risk register'. Fiona D. Patterson, Kevin Neailey designed a risk register database system in

details in 2002. In addition, risk management software called PRR (Project Risk Registers) also has been developed, which divides the risk management into two parts, namely risk plan and risk process. The most popular risk assessment software should be @risk which was developed based on Monte-Carlo Simulation technology and can enable the simulation to take place in conjunction with project planning based on Microsoft Excel 0.

Even though a lot of valuable achievements have been got, there is still no such popular risk management software that was designed specially for tunnelling project. This paper introduced risk management software based on a database system in shield tunnelling project. Firstly, this paper will describe the design and construction of the risk management system which was developed for use within a risk management methodology. And the system can provide a mathematical model and calculation platform for information sharing and communication, and realize the whole process of risk management, including risk identification, risk analysis, risk evaluation, risk decision and risk motoring.

2 THE FRAME OF SOFTWARE TRM 1.0

The development of the risk process of risk management can be divided into several phases 0. Chapman divided the risk management process into three parts that are “scope, Structure Parameter and Manipulation and Interpretation”, in this phase the safety of project was mainly researched in view of reliability theory, and risk hadn’t become the main concept in project management field. Uk MoD appeared in 1991 in United Kingdom in which Initiation Identification, Analysis, and planning management were considered the main steps. In 1997, Chapman 0presented PRAM model in which risk management process was divided into 9 parts, namely define, focus, identify, structure, ownership, estimate, evaluate, plan and management, and presented RAMP model in the following 1998 [5]. After then, several risk frameworks have been proposed, e.g. AGS (2000) 0, Dai *et al.* (2002) 0, Nadim and Lacasse (2003) 0, Fell *et al.* (2005) 0.

With some further study 0, a systematical step of risk management methodology is considered as a integrated process which is initiated at the risk analyses. It comprises five stages, given in Fig.1. Based on the above research achievement, the software also comprises 5 modules, including risk identification, risk analysis, risk evaluation, risk decision and risk monitoring. The framework of the software can be separated into 3 layers, given in Fig.2.

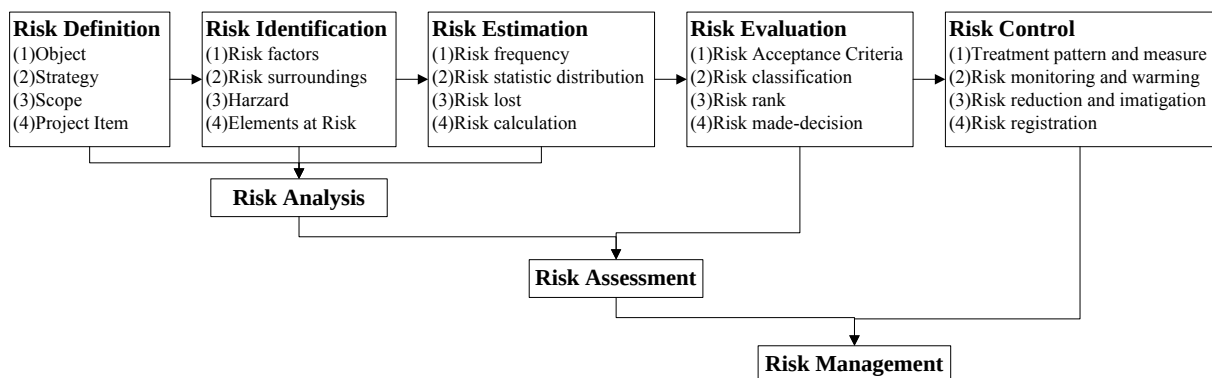


Fig.1 Risk management methodology and flowchart

From Fig.2, it is clear that the system was designed based on a risk database. The main functions of the risk database can be described as followings:

- The result should not be dependent in any way, on the case under scrutiny or on the hypothesis itself (independence)
- Store the valuable information of the project and data created in risk management process, e.g. Project item, risk factors, risk analysis and decision results;
- Offer necessary information for risk identification and calculation;

- Supply suggestion for risk decision and store the information gained from risk monitoring such risk monitoring and registration.

The basic thought or target of the software can be described as following: supported by the risk database introduced above to provide an information communication platform, and based on a systemic and objective understanding of the project through a cyclic risk management methodology to control and realize the dynamic management of the project risks. The main functions of the system can (see Fig.2):

- Store all valuable information of the the project risks in an effective way.
- Realize the risk assessment of the whole project construction in an auto-cycle process.
- Provide suggestions for risk decision and realize the risk dynamic management and control.
- Some other affiliated functions, including report creating, browsing, and so on.

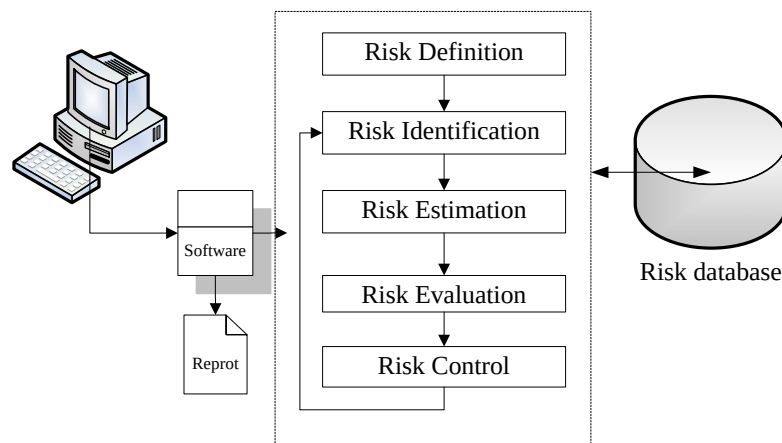


Fig.2 the hierarchy modules of the risk management software

3 THE MAIN MODULES OF SOFTWARE TRM 1.0

3.1 Risk definition

Risk is defined as the measure of the probability and severity of an adverse effect on property, life, health, environment, reputation or time delay etc. Quantitatively, risk is the product of the hazard times the potential worth of loss. So when we want to do a risk analysis for a new tunnelling project in different phases, some important information about the project need be collected firstly, e.g. the total investment, location and some general situation and surroundings. Then we should know the object of risk management, and set up the strategy and content about what or how to do the work. It is so important that risk definition can give some basic principle to let researcher or engineers catch the point to star a risk management of project quickly.

3.2 Risk identification

The aim of risk identification is to identify exhaustively all significant sources of risks within a project, as well as risk factors of those risks. The main risks which always occur or may cause serious consequence and their risk factors are summed up and stored in the risk database. They can be served as suggestions and references when identifying risks for new project.

Considering the characters of tunnelling project, the process of construction is divided into three layers, namely project, sub-project, and unit-project. Their relationships and classification are shown in Fig.3. Their relationship is designed by their own codes. For instance, if the code of a risk is R0010203001, the meaning of every part is shown in Table 1. The design interface of risk identification was given in Fig.4.

Table 1 the code design of project risk

Risk Name	Project code	Sub-project code	Unit-project code	Risk code
R	001	00102	0010203	0010203001

As is known, a risk form of expert investigation is a document which is completed by a member of a project to raise with management a new project risk. Risk form is a useful method, which may be used to formally log any type of risk; including the most frequent types of risks identified relate to the project. A typical risk forms should include many information about some Risk ID, such as description of the risk identified, a rating of the likelihood and impact of the risk's occurring, some preventative Actions to minimize the likelihood of the risk's occurring, and contingent Actions to minimize the impact to the project should the risk occur etc.. A risk form based on the method of Expert Confidence Index (ECI) was showed in table 2, which is firstly established Chen L. (2005)0. And the software of Tunnel Risk Management (TRM1.0) can build a risk form for expert investigation.

Table 2 A risk form based on the method of Expert Confidence Index (ECI)

Risk ID		Frequency/Probability		Economic lost		Personal casualty		Time delay	
Hazard	Factors	Risk Class	ECI	Risk Class	ECI	Risk Class	ECI	Risk Class	ECI

*Risk Class can be estimated by experts or engineers with Risk Matrix 0.

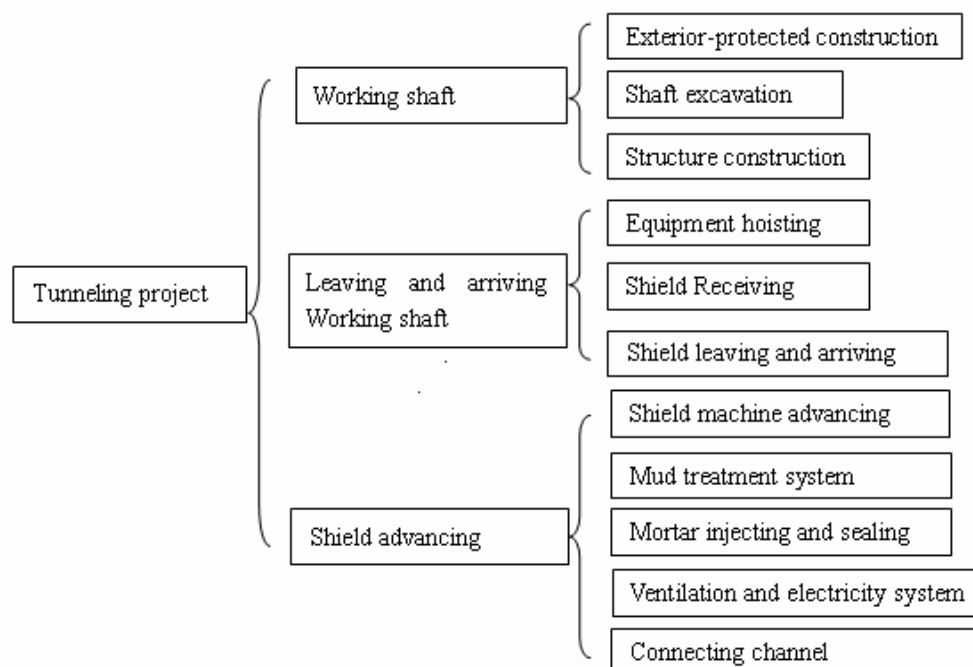


Fig.3 the hierarchy level of a shield tunnelling project



Fig.4 some interfaces' design of risk identification of a shield tunnelling project

3.3 risk estimation

The task of risk estimation is to calculate occurring probability and loss of risk, and get its potential distribution. The popular methods used in risk assessment include expert investigation method, fault tree method, fuzzy method, Monte-Carlo simulation, and so on.

In this risk management system, the used method is expert investigation method based on Expert Confidence Index (ECI), which is established and achieved by our research group 0. The content of investigation form comprises probability, economical loss, and time delay and person injury (See table 2). From the investigation result, firstly obtain the probability and loss contribution of different risk factors. Then, based on their relationship, obtain the probability and loss distribution of risks through parallel CIM method (Controlled Internal and Memory Models, CIM). The loss distribution of subproject and unit-project can be calculated by series-wound CIM model. The flow of risk assessment was given in Fig.5.

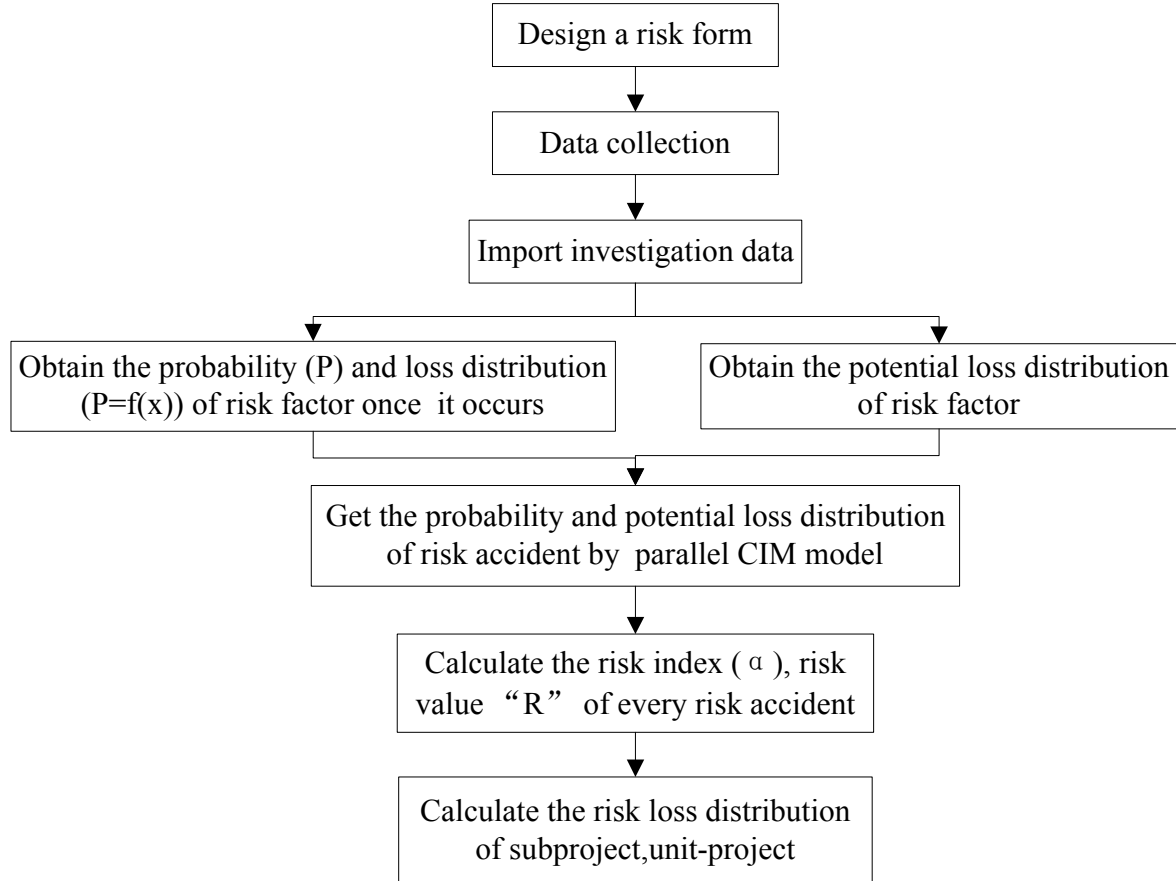


Fig.5 the flowchart of risk estimation

The formula of parallel CIM method in order to get the superposition result of C1 and C2 is given following formula:

$$P(C_a = c_a) = \sum P(C_1 = c_{1i}, C_2 = c_a - c_{1i}) = \sum P(C_1 = c_{1i}) P(C_2 = c_a - c_{1i}) \quad (1)$$

The formula of series-wound CIM method is given in formula as:

$$P(C_a = c_a) = \sum P(C_1 = c_a, C_2 \leq c_a) + \sum P(C_1 < c_a, C_2 = c_a) \quad (2)$$

3.4 risk evaluation

The criterion risk evaluation used in this system is risk index. Risk index α is a variable which represents the shape of risk loss distribution curve. It can be calculated as following formula:

$$\alpha = \begin{cases} \varpi_1 \times \varpi_2 & R \leq T \\ 1 & R > T \end{cases} \quad (3)$$

$$\varpi_1 = \frac{x}{1+x} \quad (4)$$

$$\varpi_2 = \begin{cases} \frac{R}{T} & R \leq T \\ 1 & R > T \end{cases} \quad (5)$$

If the loss C distribution function curve is continuous, then the x can be calculated by formula (6):

$$x = -\int_0^S f(c) \cdot \ln[F(c)] dc \quad (6)$$

If the loss C distribution is discrete, then the x can be calculated by formula (7):

$$x = -\sum_{j=0}^S [\ln P(C_j)] P(C_j) \quad (7)$$

The criteria of risk rank are listed in Table 4:

Table 4. the criteria of risk rank		
Risk rank	value of risk index	Describing condition
First	0~0.13	negligible
Secondary	0.13~0.29	Can be accepted
Third	0.29~0.48	Medium, need attention
Forth	0.48~0.71	Considerable, mitigation measure is necessary
Fifth	0.71~1.00	unacceptable

3.5 risk control or decision

Based on the evaluation of every risk, the risk decision can be made as following. Should the risk not be acceptable in accordance with the specified risk acceptance criteria there are principally four different ways to adopt: *Risk mitigation, risk reduction, risk transfer and risk acceptance*. The risk control measure of different risks could be selected in the following flowchart seen Fig.6.

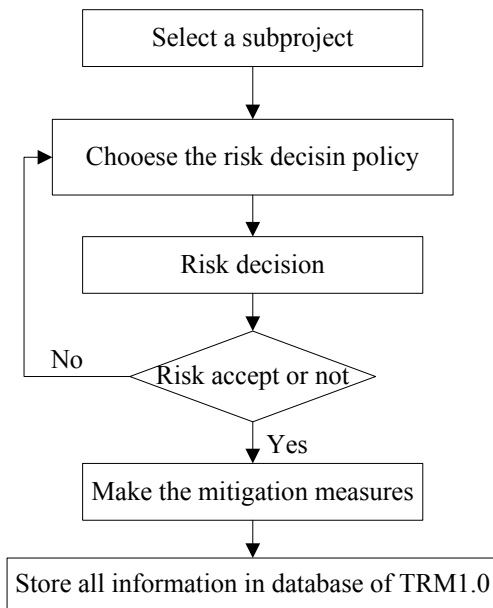


Fig.6 the flowchart of risk decision or control

Risk mitigation measure also should be made in this step. In the designed risk software TRM1.0, the usual measures for each risk accident are also summed up. They can be supplied as suggestions to user when making a decision. After a decision being made, the information will be stored in risk database of TRM1.0. The interface and risk decision was given in Fig.7.

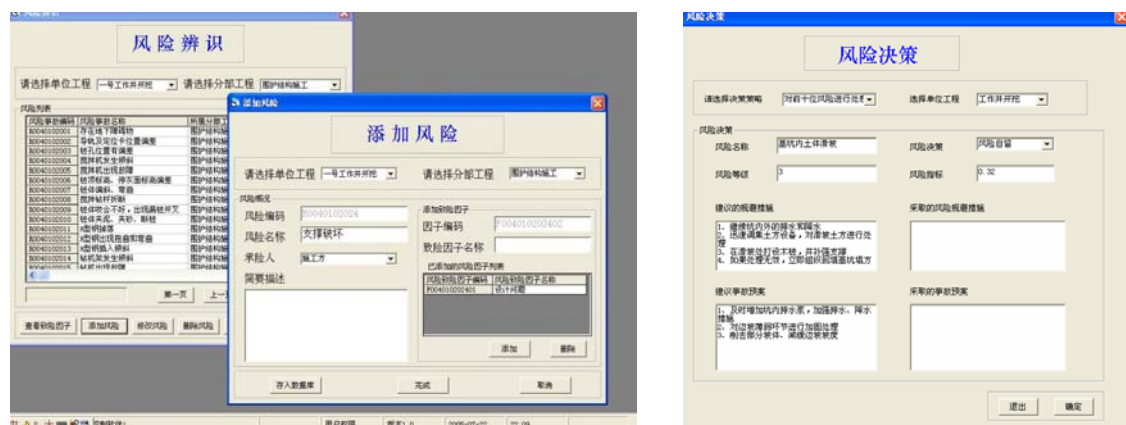


Fig.7 the flowchart of risk decision of a shield tunnelling project

As the risk management is a dynamic system, risk monitoring is one of pivotal step in risk management process. After risk analysis and decision, the very task for us is to control the risk. In order to realize it, we should know the condition of the risk development along the construction process. Based on the information we collected, we should change the risk priority and implement risk mitigation measures if necessary.

In this system, risk monitoring comprises two parts: Firstly, the monitoring of the risks which have been identified, secondly, the control of new risk which was newly identified during construction. In this step, the information stored in the database includes risk development condition, risk description and risk loss, the date and people of implementing risk mitigation measures. The interface of risk monitoring is given in Fig.8.



Fig.8 the interface design of risk monitoring of a shield tunnelling project

4 THE FUNCTIONS OF SOFTWARE TRM 1.0

With the purpose to construct an information platform for user to have an overall understanding of risk management for shield tunnelling projects, TRM 1.0 software could provide the risk condition in real time to simplify the work process, and browse for a certain risk name or data. In the end a detail report are also designed to create in the software TRM 1.0 as some affiliated functions.

Within the browsing interface, it is easy for user to get the detailed information about the risk accident, as showed in Fig.9, Unit-project and subproject, including the probability, potential loss distribution, risk index, risk decision result, whether and when mitigation measures were implemented, and so on.

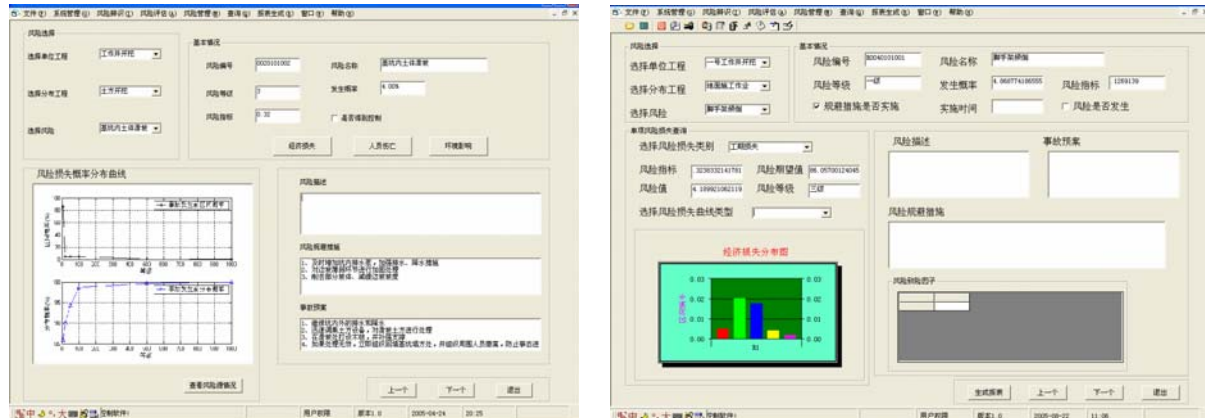


Fig.9 The interface design of single risk search of a shield tunnelling project

The software TRM 1.0 was planned at 2004, then designed and programmed at 2005 by many researchers and students in the workgroup of Prof. Huang in Tongji University, Shanghai. Then TRM 1.0 was widely used in many shield tunnelling projects in China, such as the Yangtze River Tunnel Shanghai, the Qianjiang River Tunnel of Hangzhou, and the Bay Tunnel of Tunnel. And the copyright of TRM 1.0 was registered and numbered 2006118617 in the Centre of Copyright Administration of the People's Republic of China at October 2006.

5 CONCLUSIONS

Tunnelling works are characterized by high degree of uncertainty. Engineering judgement is necessary to achieve reliable results in either hazard or risk. So the risk management of shield tunnelling projects is so important that it can identify most of engineering risks, analyze its

occurrence probability and potential loss, and make some decision to control, mitigate or reduce those risks. The geotechnical approach of risk analysis still has major needs, including reducing uncertainty in the calculation model by obtaining and analysing performance data of high quality, quantifying acceptable and tolerable hazard (and later risk) levels, and convincing stakeholders of the value added in uncertainty-based analyses. The current paper illustrated some achievement of Prof. Huang's research workgroup in recent years.

Based on a risk database, this software TRM 1.0 was designed to construct an information platform and realize the whole process of risk management, including risk identifications, risk assessment, risk evaluation, risk control (risk decision and risk monitoring). It is also testified that, using expert investigation and CIM method is a practical way to realize risk assessment and evaluation. As is known, risk management contributes to sustainable development of the engineered environment by pointing the direction for optimum solutions, mitigating natural and anthropogenic hazards and increasing awareness and preparedness. How to realize dynamic risk management during construction is the very issue of risk management which still need further study.

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