The Design of Early Warning Indexes of Safety Risk for Subway Shield Construction

Li Meng, Liu Yu*, Gong Yujie
School of Management, Wuhan University of Science and Technology, P.R.China
*Corresponding Author: jessiegyj@163.com

Abstract. Subway construction has prominent features of concealment, technical complexity and uncertainty of qualitative, even if the shield construction methods with a high safety coefficient is adopted, safety accidents would occur. The establishment of an effective early warning system for subway shield construction is one of the important means to prevent and reduce the occurrence of disasters, while the warning indexes are monitored in real time. This paper proposes an early warning indexes for safety risk of subway shield construction. Based on refers to relevant documents and combined with the results of the investigation, the indexes is designed from four aspects: organization management, site management, doer and physical objects and construction process. It provides reference for early warning and monitoring of shield construction.

1. Introduction
The traffic congestion is very serious with a rapid increase of urban population and economic. China has quickened the pace of subway construction for improving the urban traffic environment. At present, it has over 30 metro cities[1].

Shield construction has the advantages of small environmental impact, not limited by landmark environment, small occupation area and less affected by climatic conditions with being widely used in subway construction. However, a subway construction has prominent features of concealment, technical complexity and uncertainty of qualitative. Even if the shield construction methods with a high safety coefficient is adopted, a safety accident may occur. Accordingly, the establishment of an effective early warning system for subway shield construction is one of the important means to prevent and reduce the occurrence of subway construction disasters, which monitors the construction process dynamically and in real time. While the selection and formation of warning monitoring indexes is an important management link in it[2][3].

2. Composition Safety Risk Early Warning System
The risk of shield construction has a process from latency to occurrence. By a early warning is meant a dynamic supervisory control of risks in the daily construction process. It collects the basic information which generated by the risk, and compares it with the corresponding monitoring indexes to observe their variation. An early warning signal is sent to the risk management agency by the degree of deviation of the monitoring data from the warning threshold, thus the agency would control and corrects measures in time to avoid the risk event or reduce the loss after the accident. A complete early warning system for shield construction of subway covers such procedures as clear warning significance, finding warning sources, analyzing warning signs, confirming alarm degree eliminate warning risks. It as shown in Fig. 1
3. Design of Safety Warning Indexes for Shield Construction

An effective safety risk monitoring of shield construction depends on a reasonable selection of warning indexes. At present, the monitoring of shield construction is mainly based on the shield operation parameters provided by manufacturers for the lacking of systematic and unified national or industry standard in China[4]. This paper analyzes the safety risk factors of subway construction, and then combines engineering practice experience and research results, classifies and collates them by referring to existing literature[5–7], finally proposes a subway shield construction warning indexes based on current norms and standards. The index system is divided into four parts: early warning index system of safety organization management, early warning index system of site management, early warning index system of doer and physical objects, and early warning index system of construction process.

3.1. Early warning index system of safety organization management

The cause of any accident must include an mismanagement. Therefore, the safety organization and management must be strengthened to reduce and eliminate that in subway shield construction. According to the existing safety management laws and regulations and the requirements of occupational health management system (GB/T 28001-2011), this paper proposes three levels for the early warning index system of organizational management by referring to the relevant research. The index system as shown in Figure 2.
Safety Production Responsibility System

The soundness of safety organization, the clarity of safety objectives, the rationality of safety responsibility and authority setting, and the scientificity of assessment system

Safety Production Education

Safety training plan and implementation, three-level safety education, regular safety education, safety education for variant types of workers, special workers training, pre-class education

Measures and plans for safety technology

Measures and plans for preventing casualty accidents and occupational diseases

Safety Management Information

The collation, classification and preservation of safety management information

Security check

Check the implementation of the safety responsibility system, the working environment on site, the implementation of safety technical measures and the use of safety funds

Contingency plan

Exercises on emergency plan compilation

Construction team management

Operation level of construction team and shield operation ability, quality of subcontractor team and performance ability of subcontractor

Safety technical clarification

Establishment and perfection of technical submission system and implementation of safe technical submission system

Figure 2. The early warning index system of safety organization management

3.2. Early warning index system of site management

A reasonable site planning and a orderly site layout can not only greatly reduce the occurrence of safety accidents but also improve the quality of staff and workers. This has been proved by practice. Subway shield construction has the characteristics of small work size, poor working lighting conditions. The incidents of casualties are extremely prone to occur without overall on-site management. This paper proposes an early warning index system for on-site management. The index system as shown in Figure 3.

3.3. Early warning index system of doer and physical objects

Man, machine, material, method and environment are the five elements of the total quality management of enterprises. They are also the important factor in security analysis. An construction method has been determined, we analyze the other four factors. Then we set up the early warning index system of doer and physical objects for shield construction. The index system as shown in Figure 4.
3. Reasonable site layout
   Smooth and convenient roads, clear division within the area, convenient production and living of temporary facilities

3.1. Material and equipment stacking
   Classified storage of materials and equipment, material and equipment conforming to graphic design, identification clear, storage of special materials conforms to specifications

3.2. On-site safety identification
   Complete site identification, compliance, safe passage and dangerous area with safety identification

3.3. Field fire fighting
   Quantity and location of fire fighting equipment conform to the regulations

3.4. On-site first aid facilities
   Disposition of common medicines, first aid equipment, first aid kit and popularization of first aid knowledge

Figure 3. The early warning index system of site management

3.4. Early warning index system of construction process
The responsibility of construction department, supervision department and the third party monitoring unit is to find out the risk accident in time and eliminate it in the bud state with a continuous on-site inspection. It is the most obvious way to reduce the occurrence of safety incidents in the process of shield construction organization. According to the existing technical specifications and the practical experience, this paper proposes an early warning index system of safety risk in shield construction process. The index system as shown in Figure 5.
Starting/arriving of shield: Deformation index of shield well and wall top, displacement value of wall body and ground subsidence value of enclosure structure; reinforcement effect of soil in front of tunnel; installation of base, assembly frame and reaction seat; earth collapse amount of demolishing temporary wall opening; leakage and seepage of tunnel opening.

Interval structure and tunnel junction: Suitability of segment form and demolition method; reinforcement effect of actual stratum; connection construction of unimplemented segment and initial support.

Construction site monitoring: Shield Tunnel Alignment Sealing: segment breakage; segment staggering; leakage between segments; shield tail leakage; displacement of rubber water stop.

Surrounding environment: Sedimentation and inclination of buildings; sedimentation of bridge piers and adjacent piers; sedimentation and difference of underground pipelines; sedimentation of roads and surface.

Tool changing construction: Geological and environmental conditions of normal tool change sites, normal pressure or pressure tool change and control schemes and parameters; sudden tool head overhaul and tool change schemes, implementation conditions and risk prediction.

Shield construction parameters: Earth pressure; Cutter head torque; Total reasoning; Propulsion speed; Cutter head speed; Penetration; Synchronized grouting scheme; Synchronized grouting quantity.

Construction management and operation: Operation level of construction team and Shield operation ability; construction organization and management status; personnel, equipment, emergency materials and other resources in place; implementation of safety protection measures; implementation of design documents; violation of regulations; operation of safety risk management system.

Figure 5. The early warning index system of construction process

4. Conclusion
The construction of subway shield is uncertain with many safety hazards. And the establishment of an early warning system for shield construction safety with scientific and reasonable is an important measure to ensure safe construction. It can monitor the whole construction process in real time. Safety condition of construction process is judged by comparing the observed indexes with the warning indexes and analysis. Then it would be notified to all interested parties. Finally, the interested parties take effective measures to avoid of and reduce the occurrence of safety construction accidents. This paper has designed an early warning indexes for safety risk of subway shield construction. It refers to relevant documents and combines with the results of the investigation. It would provide reference frame for early warning and monitoring of shield construction.

Acknowledgments
This research was supported by National Natural Science Foundation of China (71701155), Scientific Research Program of Hubei Education Department(Q20181103).

References
[1] Miao Y. (2013) Study on safety risk management and control system of Tianjin metro construction. City, 6: 77-79.
[2] Miao Y. (2013) Study on safety risk management and control system of Tianjin metro construction. City, 6: 77-79.

[3] Li Y.H., Xu S.D., Liu J.P. (2015) A new convergence monitoring system for tunnel or drift based on draw-wire displacement sensors. Tunnelling and Underground Space Technology 49: 92-97.

[4] Huang X., Liu Q.S. (2018) Development and in-situ application of a real-time monitoring system for the interaction between TBM and surrounding rock. Tunnelling and Underground Space Technology, 81: 187–208.

[5] Chen W.K., Wang X.H. (2007) Design and analysis of early warning index system for subway construction disasters. Urban rail transit research, 10: 25-29.

[6] The S.C. R. A. (2008) Interim Provisions for Risk Assessment and Management of Railway Tunnels. China Railway Publishing House, Beijing.

[7] Chen F., Xie H.T. (2012) Study on early warning of subway construction safety based on factor analysis and BP network. Chinese Journal of Safety Sciences, 22 (8): 85-91.