

# FROM RISK INSPECTION TO KNOWLEDGE ENABLEMENT: THE EVOLUTION OF VALUE IN THIRD-PARTY ENGINEERING CONSULTING SERVICES

HUANG Jizheng<sup>1</sup>, BAI Yun<sup>1</sup>

<sup>1</sup> *BY Civil Engineering Consulting Co., Ltd., Shanghai, China*

**ABSTRACT:** With the rapid development of urban rail transit construction, the complexity and systemic nature of its engineering risks pose challenges to traditional risk management models. This paper examines the evolutionary journey of our company's third-party consulting services for the rail transit project in a Chinese city over the past three years. It systematically summarizes a comprehensive service model that evolved from basic risk inspection, progressively deepened into solution consulting and data analysis, and further expanded to include organizing technical exchange salons and external investigation and learning activities. This paper aims to elucidate how this "data-driven, knowledge-sharing, and capacity-building" service system effectively enhanced the foresight, scientific rigor, and collaboration of project risk management. Through retrospective analysis and illustration with typical cases, the paper details the service content, implementation pathways, and key outcomes at each stage. Ultimately, it distills a replicable and scalable paradigm for modern engineering risk management consulting services, offering a practical path and theoretical reflection for industry peers in transitioning from technical executors to knowledge partners.

## 1. INTRODUCTION

Urban rail transit construction is typically characterized by large scale, complex environments, technology intensity, tight schedules, and multiple stakeholders. Its engineering risks exhibit significant systematicity and dynamic coupling. Geological uncertainties, impacts on adjacent structures, and the interrelation of large-scale deep excavation and shield tunnelling construction mean that a risk in a single link can trigger a chain reaction (Yang Shucai, 2014). Concurrently, the multitude of participating units, complex management interfaces, and prominent information asymmetry issues highlight the growing limitations of traditional risk management models based on post-hoc inspections and experiential judgment in terms of foresight, refinement, and collaboration. These models struggle to meet the demand for proactive and intelligent risk prevention and control in modern large-scale projects.

In this context, independent third-party engineering consulting services have emerged and play an increasingly vital role (Liu Tianzheng et al., 2021). Traditional service models were mostly confined to compliance checks and hidden hazard identification during the construction phase. While possessing certain value, their intervention is often lagging and constrained by information access channels, making it difficult to address the root causes of risks (e.g., design solutions) or underlying trends (e.g., data anomalies). Faced with high-risk, high-tech rail transit projects, construction owners urgently need a professional partner capable of providing an independent, objective, and forward-looking perspective to assist in building a risk prevention and control system that spans the entire project lifecycle and covers both technical and managerial dimensions. Therefore, third-party consulting services must transcend the traditional role of "inspector" and transform into comprehensive knowledge service providers integrating risk early-warners, solution optimizers, data analysts, and knowledge catalysts. This evolution of value is not only an inevitable requirement for addressing complex engineering challenges but also an intrinsic driver for the sustainable development of the consulting industry itself. This paper will systematically discuss the pathways, effectiveness, and core logic of this transformation, drawing upon specific practices.

## 2. EVOLUTION AND PRACTICE OF CONSULTING SERVICES

### 2.1 FIRST STAGE: STANDARDIZED RISK INSPECTION

In recent years, BY Civil Engineering Consulting Co., Ltd. has innovatively implemented the model of "introducing third-party risk consulting through engineering insurance mechanisms" (Bai Yun et al., 2009) and has established a mature standardized inspection process and a specialized checklist for underground rail transit works within Shanghai's rail transit construction.



Figure 1: Third-party risk control process (Shi Zheng et al., 2024)

At the end of 2022, the rail transit construction in a certain city entered a peak period. Its group's safety and quality department faced the challenge of mismatched management capacity and the number of high-risk projects. Consequently, the group collaborated with the engineering insurance company to introduce our firm as a third-party consulting service provider, aiming to systematically enhance the identification, process control, and emergency response capabilities for engineering construction risks.

The service at this stage adopted "controlling major risks, identifying construction hazards, and providing solutions" as its core methodology. The goal was to systematically reduce the probability of accidents and losses, decrease insurance claims, and foster a tripartite win-win ecosystem involving the owner, insurance company, and consultant. Inspection work focused on line-level major risks, aiming to identify deficiencies in technology, management, and awareness among the project's five responsible parties and to provide actionable rectification pathways. Expert inspections served as a supplement and deepening of daily project control, based on the project's own monitoring data but not substituting for its primary responsibility.

From late 2022 to 2023, our company inspected 30 projects across 6 lines in the city (including 9 shield tunnelling projects and 21 deep excavation projects), cumulatively identifying 45 defects and proposing 630 rectification suggestions. At year-end, based on the annual data, we systematically summarized common technical challenges faced in the city's rail transit construction, such as tunnel segment floating control, optimization of segment ring assembly for large-diameter shields on regional lines, deep excavation deformation and confined water control, quality of retaining structure construction, and strut axial force monitoring. We provided systematic optimization suggestions and alternative construction methods. Additionally, from a management perspective, we proposed suggestions including specialized research on design parameters, owner-led experience exchange sessions, enhanced subcontractor management, and excavation deformation control competitions, offering new ideas for the owner's subsequent management decisions.

## 2.2 SECOND STAGE: SOLUTION CONSULTING AND DATA ANALYSIS

During the first year of service, we jointly identified two key bottlenecks with the client: first, the root causes of major risks often lie in the design phase, making intervention only during construction less effective; second, there exists a multitude of non-quantifiable and trend-based risks that can only be revealed through data mining.

### 2.2.1 Solution Consulting

To control risks at the source, we collaboratively designed a new service category, solution consulting, distinguishing it from routine construction inspection. The service closely aligned with the actual needs of the construction branch companies and project sites. Targeting projects with high risks and multiple feasible technical pathways, we engaged in early intervention during the design phase. We formed specialized expert teams to conduct preliminary assessment and optimization of design solutions from a risk perspective.

In 2024, solution consulting services covered 19 projects, accounting for 40% of the annual service volume. This service effectively assisted projects in optimizing design details and supplementing contingency plans for risk blind spots. A typical case: the original design for a station entrance/exit pedestrian underpass employed the pipe jacking method. However, unidentified historical pile foundations were discovered before construction, posing extremely high risks for obstacle removal via the pipe jacking machine. Upon evaluation and recommendation by our experts, the final solution was changed to open-cut method combined with road diversion, significantly reducing implementation risks and technical difficulties.

### 2.2.2 Data Analysis

To address hidden quality risks like leakage in deep excavations, we developed a statistics-based analytical method for diaphragm wall construction time-series data. This method systematically diagnoses and warns of diaphragm wall construction quality by analyzing the time distribution patterns of key processes—trenching, slurry replacement, reinforcement cage lowering, and concrete pouring—combined with the concrete fill factor. In 2024, this method was applied to 12 projects, providing targeted basis for subsequent treatment.

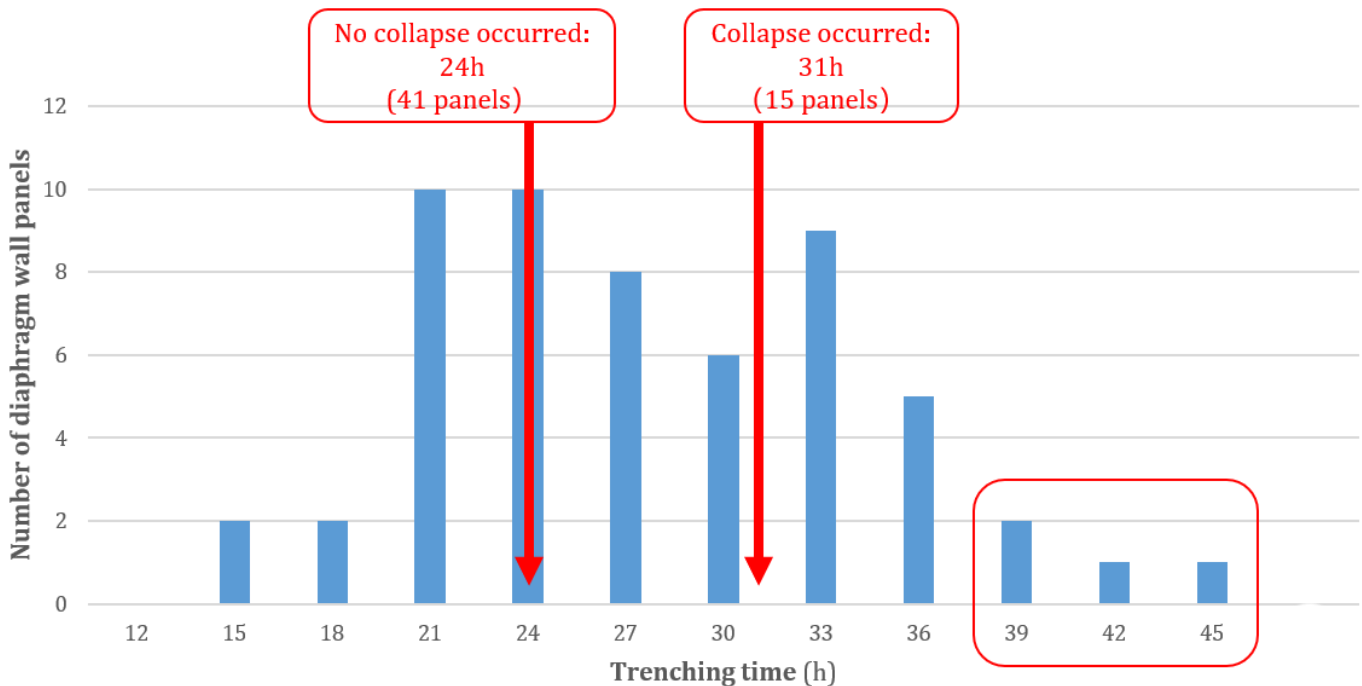


Figure 2: Example of diaphragm wall construction data analysis

Simultaneously, we focused on the massive PLC data generated during shield tunnelling. By classifying, reducing dimensionality, and extracting feature labels from the data, we established a data reduction and analysis methodology. Plotting scatter diagrams and histograms of key parameters and interpreting data patterns by experienced experts enables effective identification of abnormal excavation parameters, deviation trends in shield attitude, and potential ground disturbance risks.

From 2024 to 2025, we conducted pilot analyses on several shield tunnelling intervals, with results receiving high acclaim from the owner. Building on this foundation, we collaborated with the rail transit group and the shield data platform developer to co-develop a real-time shield data analysis function module. This module dynamically generates analytical charts, assisting the owner in achieving real-time perception and early warning of shield tunnelling risks.

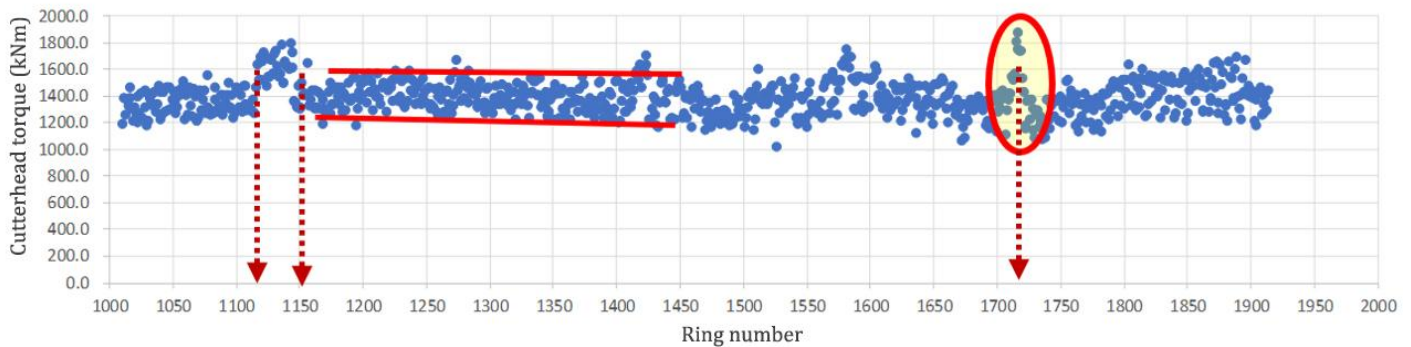


Figure 3: Example of key shield tunnelling parameter data analysis

### 2.3 THIRD STAGE: TECHNICAL EXCHANGE AND INVESTIGATION & LEARNING

Entering the later stage of service, we recognized that the key to achieving long-term effective risk control lies in enhancing the technical philosophy and management capabilities of project participants. Therefore, the focus of the third stage shifted towards knowledge transfer and capacity building.

On one hand, we regularly organized "Technical Exchange Salons", inviting major design and construction units involved in the city's rail transit projects. Salon topics focused on cutting-edge technologies and common challenges. Successful discussions have included diaphragm wall joint techniques, emerging ground improvement methods like MJS/TRD, optimization of dewatering and support systems in soft ground, risk handling for shield reception, relationship between excavation parameters and surface settlement, and control strategies for shield tunnelling under major risk sources. These salons promoted cross-organizational technology sharing and experience exchange.

On the other hand, we implemented a "Capacity Enhancement Plan". First, we conducted specialized training for personnel in the owner's safety and quality department, explaining key inspection points and risk control methods in conjunction with the inspection checklist. Second, based on project characteristics and needs, we recommended and organized visits and investigations to exemplary domestic and international engineering projects for the owner's management personnel. This facilitated broadening their horizons through on-site learning and adopting advanced management models and engineering techniques.

## 3. SERVICE UPGRADE CORE DRIVERS

### 3.1 THIRD-PARTY VALUE

The five responsible parties must balance multiple objectives including quality, safety, schedule, and cost. Under practical pressures, the weighting of safety risks may be inadvertently reduced, leading to insufficient safety margins or inadequate measures (Zhao Tingsheng et al., 2017). Simultaneously, their internal technical capabilities may find it difficult to fully address the cutting-edge challenges across all specialized subfields. Third-party consulting units are independent of the project responsibility system.

Their core value and foundation lie in focusing on risks and providing objective, professional judgments. This independence enables them to continuously explore any methods conducive to reducing engineering risks and to constantly upgrade their services, thereby becoming a trusted "external brain for risk control" for the owner.

### **3.2 CLIENT NEEDS**

The owner's demand for risk control is not static. As projects progress, experience accumulates, and the external environment changes, their needs deepen from initially "having someone inspect" to "inspecting accurately", "preventing effectively", and "managing well". Third-party consultants must maintain acute insight to actively perceive and respond to the escalation of client needs, continuously iterating their service offerings, and shifting from passive response to active enablement to achieve long-term strategic synergy with the client.

### **3.3 ERA DEVELOPMENT TRANSFORMATION**

The maturity of technologies like big data and the Internet of Things, along with decreasing hardware costs, have made in-depth mining of construction process data possible. Data analysis acts like an "engineering medical report", providing quantitative basis for risk diagnosis. Concurrently, knowledge management tools and online collaboration platforms have made cross-organizational, cross-regional technical exchange and knowledge accumulation more efficient. Technological development provides crucial support for consulting services to transition from "experience-driven" to "data and knowledge dual-driven".

## **4. CONCLUSION**

This paper systematically reviews and summarizes a comprehensive, enabling service model for third-party engineering consulting that started from standardized risk inspection, gradually evolved into solution consulting and data analysis, and ultimately deepened into technical exchange and investigation & learning. Practice has proven that this evolutionary pathway of "data-driven, knowledge-sharing, and capacity-building" effectively overcomes the lag and fragmentation of traditional risk management, significantly enhancing the foresight, systematicity, and collaboration of risk management in rail transit engineering. Consequently, the role of third-party consulting has successfully transformed from a mere technical verifier into a knowledge partner and co-builder of risk management capability for projects.

Looking ahead, with the further development of technologies such as artificial intelligence and digital twins, engineering risk management will advance towards a more intelligent and visual new stage. Third-party consulting services will continue to deepen their capabilities in areas like intelligent data analysis, risk prediction simulation, and virtual training exercises, aiming to build an intelligent risk control ecosystem covering the entire chain of "perception-diagnosis-warning-decision-learning". Simultaneously, the boundaries of knowledge enablement will further expand, extending from a focus on technical risks to broader areas such as project governance, organizational learning, and resilience building. We believe that third-party consulting, with its 持续 value evolution, will play an even more critical role in safeguarding major infrastructure safety and promoting the high-quality development of the engineering construction industry.

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***M.Eng., P.E., Huang Jizheng: Author1***

***BY Civil Engineering Consulting Co., Ltd.***

***E-mail address: yiyanghepan@qq.com***

***Prof., Bai Yun: Author2***

***BY Civil Engineering Consulting Co., Ltd.***

***E-mail address: 09150@tongji.edu.cn***