



# Analysis and Research of Safety Quality Management Data of Power Network Infrastructure

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**Abstract.** The safety and quality management of transmission and transformation projects in State Grid Corporation Limited has always been a focus for infrastructure construction managers. Conducting high-quality and efficient safety and quality management work will lay a solid foundation for the safe, stable, and high-quality development of the power grid. In today's era of technological advancement, integrating digitalization and intelligence into the safety and quality management of infrastructure construction is very important. With the help of the "e-Infrastructure" 2.0 management system of the State Grid, this paper analyzes the core elements of "personnel, machinery, environment and management" by means of data analysis, so as to improve the data utilization efficiency in the e-infrastructure 2.0 system, give full play to the value of data, and further improve the safety quality control level of power transmission and transformation projects. At the same time, feasible quantitative indicators are discussed for the data in the system, and the infrastructure safety quality management is quantified, so as to improve the utilization rate of infrastructure data and tap the application value of data, so as to further enhance the efficiency of infrastructure safety quality management.

**Keywords:** Power transmission and transformation project, Capital construction, Data analysis, index

## 1 Introduction

State Grid Corporation Limited has more than 2700 transmission and transformation projects of 35 kV and above under construction every day, with more than 100,000 people working simultaneously during peak construction periods. In 2024, several ultra-high voltage projects were started, with many construction sites, wide coverage, and multiple risks, making control difficult. At the same time, safety management generally has a target assessment defect of "0 points for accidents, 100 points for no accidents". In 2023, the company fully carried out the annual theme activity of "grasping responsibility, refining management, and solidifying the foundation", which made up for this defect to some extent. However, the company's strategic layout and the construction of

a new type of power system have also put higher demands on the safety of power grid construction. The safety management of power grid construction needs further strengthening of control. The general quality management of projects is verified through on-site quality inspection and research, as well as remote safety and quality management[1-2], but the existing methods are difficult to serve the whole process quality control mechanism. The control requirements of key links such as "planning", "quality testing", "video control", "quality acceptance", and "performance assessment" need to be further improved. There is an urgent need to formulate a corresponding system of safety and quality control measures for power grid construction, propose technical means to improve the quality control of power grid construction, and guide the improvement of on-site quality management capabilities for transmission and transformation projects.

It is necessary to strengthen the safety and quality management of power grid construction sites, further quantify the evaluation indicators of safety and quality control on the basis of the original extensive management, and continuously improve and summarize to enhance the level of safety and quality control.

## **2 Exploration and Application of the "e-Infrastructure" 2.0 System**

With the continuous advancement and widespread application of intelligent technology, the field of safety management has ushered in a revolutionary change[3-6]. Traditional safety management relies on experience judgment and extensive management methods, while now, data analysis and intelligent refined management have become the new development trend. This transformation has shifted the focus of enterprise safety management from post-event handling and mid-event control to a greater emphasis on pre-event prevention. That is, through intelligent technology, potential risks are predicted and warned in advance, so that effective measures can be taken before the occurrence of accidents to minimize losses. This proactive safety management approach not only improves the overall safety level of the enterprise but also significantly reduces the probability of accidents, providing a solid guarantee for the sustainable development of the enterprise. In the current complex and changing socio-economic environment, the application of intelligent technology in safety management is particularly important. It is not only related to the survival and development of the enterprise but also directly related to the stability of society and the safety of people's lives and property, thus it has far-reaching practical significance and broad development prospects.

State Grid Corporation Limited took the lead in developing the "e-Infrastructure" 2.0 platform in August 2022 to improve the quality and efficiency of ultra-high voltage project management through digital means. The "e-Infrastructure" 2.0 platform achieves close and efficient cross-professional collaboration. The ultra-high voltage project contract payment management function on the platform covers contracts from more than a dozen professions such as construction, supervision, and design. By opening up the data links between business systems such as the economic law system and enterprise resource planning (ERP) and financial systems, it associates the core business of ultra-high

voltage project construction progress with technical and economic professionals, automatically tracks the performance of contracts, and achieves centralized and efficient financial payment for ultra-high voltage projects. At the same time, the platform automatically statistics the construction progress of ultra-high voltage projects by associating work tickets and quality acceptance progress; by associating construction drawings with quality acceptance and change visas, it achieves "locking the diagram upon acceptance and issuing the diagram upon change".

As shown in Figure 1, to achieve full-element monitoring and auxiliary analysis at the construction site, the "e-Infrastructure" 2.0 platform uses big data and cloud computing technology to deeply analyze automatically collected site data, predict potential problems, and issue early warnings to help managers take timely measures. The platform can also monitor the personnel input, construction progress, and construction drawing delivery of ultra-high voltage projects in real-time, providing support for construction managers at all levels to judge the construction situation. Since the launch of the "e-Infrastructure" 2.0 platform, it has been fully applied to 13 ultra-high voltage projects, supporting 19 construction management units to carry out risk hidden danger investigation, work plan preparation, material arrival acceptance, environmental protection problem management, and project quality acceptance[7].

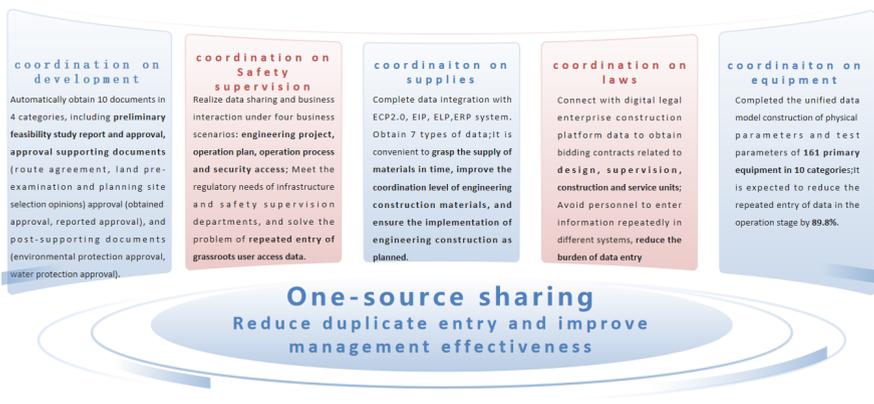


Fig. 1. e-Infrastructure 2.0 System Functions.

### 3 Classification and Analysis of "e-Infrastructure" 2.0 System Data

However, at present, the application of data in the e-Infrastructure 2.0 system is still mainly at the basic level of collection and statistics, and the deep mining of data is obviously insufficient, and its potential application value has not been fully realized. This situation has led to the role of data in guiding subsequent safety management work not being effectively reflected, and there is an urgent need to strengthen and optimize. Therefore, how to use data analysis methods to carry out core element analysis of "personnel, machinery, environment, and management" to improve the efficiency of data

utilization in the e-Infrastructure 2.0 system and give full play to the value of data, thereby further improving the safety and quality control level of transmission and transformation projects, is a research direction worth thinking about. In response to infrastructure site data from different sources such as e-Infrastructure 2.0, the author analyzes the data from four aspects: personnel, machinery, environment, and management, as shown in Figure 2:

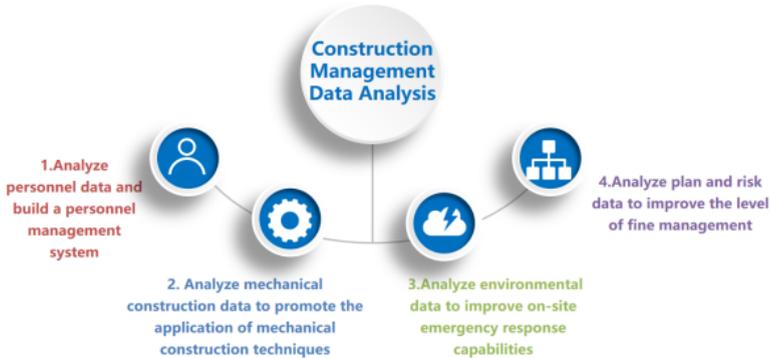


Fig. 2. Personnel, Machinery, Environment, and Management Data Analysis Angles.

### 3.1 Personnel Data Analysis

Firstly, in analyzing personnel data and constructing a construction personnel management system, data related to personnel from the e-Infrastructure 2.0 system, State Grid Technical College, State Grid Corporation's two-level monitoring platform, on-site inspections, and company violation notices are collected. Then, work such as new team and personnel analysis, ghost team analysis, personnel abnormal flow analysis, construction layer team safety lean management, and team member change analysis is carried out, as follows:

(1) Analyze new personnel and teams to mainly determine whether the teams and personnel in the station team meeting and personnel admission have appeared in the project;

(2) Analyze "ghost teams" to mainly determine whether the teams in the station team meeting that have work recently are working on the same day, and whether the admitted teams have carried out work recently;

(3) Analyze personnel abnormal flow to mainly determine whether the number and proportion of participating personnel changes exceed the set value, whether the number of times the personnel change projects in a short term exceed the specified value, and whether the change in the number of provinces where personnel belong exceeds the set value, to understand the flow of participating personnel between different provinces;

(4) Analyze changes in construction team members to mainly determine whether key positions have personnel changes; the number and proportion of general positions exceed the set value;

(5) Analyze the safety lean management of the construction layer team to mainly determine whether the age, personnel resume, certificate holding, etc., in personnel basic information match the current project, whether the personnel admission scores are complete and qualified, whether the violation level and quantity involved in violation data exceed the set value, and whether there are situations involving unqualified teams.

By analyzing the collected personnel data, timely grasp the dynamic changes of the team, take corresponding measures according to the analysis results, reduce the disorderly flow of personnel, improve personnel control efficiency, and support the construction of a normalized personnel management system.

### 3.2 Mechanization Data Analysis

In analyzing mechanized construction data and promoting the application of mechanized construction methods, risk reduction rate analysis, innovative method application proportion analysis, and non-compliant construction warning are carried out through the analysis of mechanized construction-related data, as follows:

(1) Carry out innovative method application rate analysis to determine whether the construction method in the work ticket belongs to an innovative method;

(2) Carry out non-compliant construction warning to determine whether the construction method in the work ticket is consistent with the risk base account, and whether the risk base account has changed.

By analyzing the collected mechanized construction-related data, we can timely understand the level of on-site mechanized construction, provide reasonable and feasible mechanized construction plans for the site, promote the application of mechanized construction methods, and thus reduce the risk of on-site construction safety accidents.

### 3.3 Environmental Data Analysis

In analyzing environmental data and improving on-site emergency response capabilities, environmental data is judged to carry out severe weather warnings, high slope terrain warnings, debris flow area analysis, fire analysis, and flood analysis, as follows:

(1) Issue severe weather warnings, whether there is work in the weekly plan next week; combine meteorological information to determine whether there is severe weather (rain, snow, and other severe weather and debris flow, flood disasters, etc.) on the same day, and judge whether the process is closely related to severe weather such as deep foundation pits, high-altitude operations, hoisting operations, and welding operations;

(2) Issue high slope terrain warnings, determine whether the project location and operation part latitude and longitude are located in high slope areas, and issue warnings in combination with meteorological information;

(3) Analyze debris flow areas, determine whether the project location and operation part latitude and longitude are located in debris flow areas, and issue warnings in combination with meteorological information;

(4) Carry out fire analysis, determine whether the project location and operation part latitude and longitude are located in forest and grassland areas, and issue warnings in combination with meteorological information;

(5) Carry out flood analysis, determine whether the project location and operation part latitude and longitude are located in river areas, and issue warnings in combination with meteorological information.

By analyzing the collected meteorological and environmental data, carry out precise meteorological forecasting, and analyze special terrain to improve on-site emergency response capabilities and remind the site to stop work in time when necessary.

### 3.4 Management Data Analysis

In analyzing plan and risk data and improving refined management level, data from the e-Infrastructure 2.0 system, the company's two-level monitoring platform, on-site inspections, and company violation notices are collected to carry out duty analysis, full-process risk control rate analysis, load capacity analysis, operation continuity analysis, key project warnings, operation content change analysis, new supervision, and construction unit warning analysis, as follows:

(1) Carry out duty analysis to determine whether the arrival rate of high-risk operations is not reaching the set value, and pay attention to whether the safety director meets the requirement of full coverage of all operation points within a week;

(2) Carry out full-process risk control data analysis to determine whether the full-process risk control rate reaches the set value;

(3) Carry out team load capacity analysis, mainly to determine whether the number of projects, the number of teams operating at the same time, the number of people operating at the same time, the number of high-risk operations, and the number of high-risk operations of the construction unit exceed the maximum value in the past three years;

(4) Carry out operation continuity analysis to determine whether the proportion of operation days between the first date of the station team meeting and the current date is lower than the set value;

(5) Carry out operation content change analysis, when the operation ticket (line) process first appears with tower group, guide wire words triggers a warning, when the operation ticket (transformer) process first appears with electrical, primary, secondary words triggers a warning;

(6) Carry out new supervision, construction unit warning analysis to determine whether the supervision, construction unit is undertaking a project of a certain provincial company for the first time;

(7) Carry out key project warnings, combine the above information to use the layer analysis method for scoring calculation, and comprehensively determine whether it is a high-risk project.

By analyzing the collected plan and risk-related data, the site safety management is analyzed throughout the process, improving the quality and efficiency of site safety management and the refined management level of construction site construction.

After analyzing the collected data, it is necessary to further concretize the infrastructure data analysis through quantitative means. The author will study the corresponding management quantitative indicators from the aspects of safety and quality to improve data utilization efficiency and explore application value.

## 4 Creation of Safety Management Quantitative Management Indicators

### 4.1 Determination of Safety Management Quantitative Indicators

State Grid Corporation has formulated the safety management theory of controlling the operation plan, operation personnel, and operation risks. The main purpose is to reduce accidents by inspecting and urging managers at all levels to fulfill their safety responsibilities. To this end, the author has conducted a more in-depth summary and induction of safety management quantitative indicators and has sought expert opinions and suggestions. Based on this infrastructure, a quantitative indicator evaluation system including full-process risk control rate, line construction safety risk reduction rate, provincial company safety management lean rate, operation layer team safety management lean rate, and information system data accuracy rate has been formed to provide theoretical support for the e-Infrastructure 2.0 system.

#### 4.1.1 Full-Process Risk Control Rate (FRCR).

The full-process risk control rate indicator refers to the proportion of all level 3 and above risks that have been closed in the project to fully implement the full-process risk control requirements.

$$\text{FRCR} = \frac{\text{The number of CR}}{\text{The number of Level 3 risks}}$$

CR means the completed risks that can fully implement the whole process of risk control requirements. Level 3 risks means the risks at level 3 and above in the approved risk manual. Traditional risk control only controls the implementation of safety measures during the risk, but the size of the risk itself is basically determined at the moment the design drawing is issued[8-10]. Mid-event control cannot solve the problem of risk size from the source. Therefore, we propose the concept of full-process risk control from the perspective of pre-event reduction, mid-event control, and post-event assessment. Pre-event reduction: The design unit optimizes the line path and clarifies the construction method to truly achieve the application of innovative methods, and the risk level can no longer be further reduced. Mid-event control: All participating operators have undergone pre-job training and passed the exam, issued valid work tickets, and the operation process is monitored by remote cameras throughout the process; managers at all levels are on duty; construction strictly implements the construction method specified in the design; no serious violations against safety mandatory measures are found; the risk ends with the completion of the cancellation process; duty control is effectively tracked throughout the process.

#### 4.1.2 Line Construction Safety Risk Reduction Rate (SRRR).

The line construction safety risk reduction rate refers to the proportion of all level 3 and above risks that have been closed in the project to fully implement the full-process risk control requirements.

$$\text{SRRR} = \frac{\text{Number of actual use of construction method}}{\text{Nnumber of foundations of the project} \times 3}$$

Since 2020, State Grid Corporation has actively promoted the research of innovative methods with the concept of "intelligence reduces people, mechanization replaces people", and established an innovative method system map, focusing on promoting drilling machine excavation foundation, excavator excavation foundation; crane, seat pole group erection of iron tower; intelligent centralized visualization tension and release line, etc., to reduce on-site operators and improve safety factors by improving the level of intelligence and mechanization.

#### 4.1.3 Provincial Company Safety Management Lean Rate (SMLR).

The provincial company safety management lean rate refers to the proportion of projects managed by the provincial company in a lean manner to the total number of projects.

$$\text{SMLR} = \frac{\text{The number of projects in lean management}}{\text{The number of Total works}}$$

The engineering managed by the provincial company in a lean manner refers to:

- (1) The responsible person of the Ministry of Construction has carried out the work in place;
- (2) The provincial company's safety combing is accurate and tracked in a timely manner;
- (3) The engineering risk level is accurately divided and managed as required;
- (4) The operation plan, operation personnel, and operation risk control of level 2 and 3 risks are in place.

#### 4.1.4 Operation Layer Team Safety Management Lean Rate (TSMR).

The operation layer team safety management lean rate refers to the proportion of qualified and well-controlled operation layer teams to the total number of teams.

$$\text{TSMR} = \frac{\text{Number of teams that meet the requirements}}{\text{Total number of teams}}$$

Qualified operation layer teams refer to:

- (1) Ability to meet requirements: The team's backbone has enough work experience, understands the requirements of the operation, and has passed the company's unified pre-job training exam.
- (2) Identity to meet requirements: The team's backbone signs a standard labor contract with the construction unit and is engaged in work that matches its responsibilities on the site.
- (3) Organization to meet requirements: The team's backbone and core subcontracting personnel are familiar with each other, safety mandatory measures are organized and implemented, the team's backbone arrives before the team's personnel start work, and the team's personnel complete work before leaving the site.

(4) Access to meet requirements: The team's personnel pass the safety supervision access and are all included in the e-Infrastructure real-name control, and are approved to enter the operation site.

(5) Equipment to meet requirements: The team's safety protective equipment, main tools or materials are provided by the construction unit (or professional subcontracting unit), and are used correctly on the site.

#### 4.1.5 Information System Data Accuracy Rate (IDAR).

The information system data accuracy rate refers to the proportion of valid data reported in the information system to the total data.

$$\text{IDAR} = \frac{\text{The number of qualified information system data items sampled}}{\text{Total number of system data items sampled}}$$

Among them:

(1) The spot check data includes 5 types of information, such as the real name system information of the spot check personnel, the attendance of personnel, the station class meeting, the operation content, and the arrival of the post.

(2) Each random check within the random check period, 20 pieces of each type of data, a total of 100 pieces of data, and check with the actual situation.

## 4.2 Determination of Quality Management Quantitative Indicators

### 1) Full-Process Quality Control Rate.

The full-process quality control rate mainly includes three indicators: equipment and material entry inspection pass rate, main equipment test and commissioning pass rate, and system commissioning pass rate.

#### Equipment and Material Entry Inspection Pass Rate (EMPR)

$$\text{EMPR} = \frac{\text{The number of EQ}}{\text{Number of units (pieces) to be tested}}$$

EQ means the equipment material tables (pieces) qualified for the quality test of the project.

#### Main Equipment Test and Commissioning Pass Rate (ETPR)

$$\text{ETPR} = \frac{\text{The number of EP}}{\text{Total number of main equipment}}$$

EP means the main equipment that passes the test and debugging of the project at one time.

#### System Commissioning Pass Rate (SCPR)

$$\text{SCPR} = \frac{\text{The number of PPO}}{\text{Total number of projects put into operation}}$$

PPO means the projects that the unit puts into operation through the system at one time.

#### Standard Production Inspection Supervision Pass Rate(SIPR)

$$SIPR = \frac{\text{The number of PM}}{\text{Works supervised by random inspection}}$$

PM means the projects passed by the State Grid company to meet the standard and put into operation.

**2) Green High-Quality Standardization Rate**

Green high-quality standardization rate = standard production pass rate × 60% + green construction evaluation score rate × 40%.

**3) Online Control Rate**

$$\text{Online control rate} = \frac{\text{total number of quality professional function modules applied}}{\text{total number of new projects started} \times 6}$$

**4.3 The Application of Quantitative Indicators**

**4.3.1 Application of Quantitative Indicators of Safety Management.**

We extracted two projects A and B in Hunan area. The terrain, voltage level and social environment of the people around the two projects are basically similar. The relevant parameters of the two projects are statistically calculated as shown in Table 1.

**Table 1.** Safety management indicators of A&B project

	<b>FCR</b>	<b>SRRR</b>	<b>SMLR</b>	<b>TSMR</b>	<b>IDAR</b>
Project A	75%	90%	/	65%	82%
Project B	95%	100%	/	95%	98%

From the data, the five indicators of project A are all lower than those of Project B. Theoretically, the safety and quality management of Project A should be worse than that of Project B. In fact, Project A has been found two serious violations in succession in multiple inspections organized by the company, while Project B has not been found serious violations in the inspection, and the actual situation is consistent with the quantitative indicators. It shows that the five quantitative indicators can truly reflect the actual control effect on site.

**4.3.2 Application of Quantitative Indicators of Quality Management.**

We extracted two projects C and D in the northern Hebei region. The terrain, voltage level and social environment of the people around the two projects are basically similar. The relevant parameters of the two projects are statistically calculated as shown in Table 2.

**Table 2.** Quality management indicators of C&D project.

	<b>EMPR</b>	<b>ETPR</b>	<b>SCPR</b>	<b>SIPR</b>
Project C	98%	100%	100%	100%
Project D	97.14%	99.15%	100%	97.30%

From the data point of view, three of the four indicators of project D are lower than that of project C. Theoretically, the safety and quality management of Project D should

be worse than that of project C. In fact, one quality violation that triggered shutdown was found in the inspection organized by the company for Project D, and the actual situation is consistent with the quantitative indicators, indicating that the quantitative quality indicators can truly reflect the actual control effect of the site.

## 5 Conclusion

The establishment of key indicators for the safety and quality management of transmission and transformation project construction can urge various transmission and transformation projects to take effective measures to increase safety control. By formulating quantitative indicators, the application value of data in the e-Infrastructure system can be further excavated, and the role of data can be played. This paper draws the following conclusions:

(1) By analyzing the data of personnel, machinery, environment, management and other aspects of the "e infrastructure" 2.0 system, determine the application mode of the data;

(2) According to the data available in the system, formulate quantitative indicators to make the safety and quality management of the engineering site more refined;

(3) Improve the safety and quality management level of power transmission and transformation projects with the help of e Infrastructure 2.0 system data analysis and index application.

In the future, on the premise of statistical data of various indicators, in combination with on-site safety inspection and investigation and remote safety and quality management and other means, we can effectively grasp the actual situation of the site, find out the urgent problems of on-site safety and quality control, and verify the implementation of indicator control. By comparing the indicators with the site, we can achieve the effect of indicators guiding the site and improving the indicators on the site. At the same time, we can constantly analyze and summarize the existing problems in future applications and put forward technical suggestions for improvement, so as to further improve the safety and quality management indicators and improve the management level.

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