Indicator System for Benchmarking Smart Construction Sites in Power Transmission and Transformation Engineering

Liyu Xia*, Wan He, Guangrui Tang, Jiaping Han

State Grid Energy Research Institute, Beijing, China

* Corresponding author: xialiyu@sgeri.sgcc.com.cn

Abstract. The selection of benchmark projects for modern smart construction sites can promote the sharing of excellent practices and beneficial experiences in power grid construction, and better leverage the role of infrastructure profession in driving the high-quality development of the power grid. Considering the characteristics of smart construction sites for power transmission and transformation engineering, this study selects 30 evaluation indicators in 10 aspects from the dimensions of professional management and means to construct an evaluation indicator system for smart construction sites of power transmission and transformation engineering. Collect scores from infrastructure management experts and calculate the weight of each indicator based on the Analytic Hierarchy Process (AHP). The evaluation indicator system for benchmark projects of smart construction sites for power transmission and transformation engineering can comprehensively assess the construction level of the projects, identify deficiencies and difficulties in the construction process, and support power grid enterprises in achieving excellence throughout the entire process of power transmission and transformation engineering.

Keywords: Power transmission and transformation engineering, Smart construction sites, Benchmark project, Indicator system

1 Introduction

The complexity, severity, and uncertainty of the current economic development environment have escalated. The Party Central Committee emphasizes the need to promote a positive policy of stabilizing expectations, growth, and employment, continuously driving progress in transforming modes of development, adjusting economic structures, enhancing quality, and increasing efficiency. Accelerating the construction of transmission and transformation engineering is the mission of the power grid construction system to deeply implement the new strategy of energy security featuring "Four Reforms and One Cooperation," and an important measure to fully serve the work of the Party and the nation [1]. Building a benchmark project for smart construction sites is an important task of the power grid construction system. The power grid construction system

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must be based on serving the "Carbon Peaking and Carbon Neutrality Goals" and building a new power system, continuously improving the backbone grid, comprehensively improving the ability to optimize energy allocation, and helping to build a clean, low-carbon, safe and efficient modern energy system [2].

The selection of benchmark projects for modern smart construction sites can promote the sharing of excellent practices and beneficial experiences in power grid construction[3], and better leverage the role of infrastructure profession in driving the high-quality development of the power grid. From the perspective of the macro environment, the investment in power grid projects during the "14th Five-Year Plan" period will continue to maintain high growth, and for a period of time in the future, the infrastructure profession will still face the intertwined impact of the triple problem of "completing construction tasks, preventing and controlling safety risks, and promoting reform and transformation". The external environment of smart construction site benchmark projects is constantly changing, necessitating iterative updates to the corresponding evaluation indicators and methods. From the perspective of power grid enterprises, benchmark projects for smart construction sites constitute an important task in lean management. A scientific and reasonable evaluation of the construction level of modern smart construction site benchmark projects for power transmission and transformation engineering, utilizing evaluation indicators, can effectively support various smart construction site projects in identifying their strengths and weaknesses, which holds practical significance.

Wang Xiaohui et al. (2019) classified and screened general indicators for social benefit evaluation using methods such as fuzzy network analysis and cluster analysis from the dimensions of economic development, social development, and resource and environmental development to form a set of general indicators. Based on the characteristics of power transmission and transformation projects, they adopted a neural network model to extract a set of characteristic indicators for these projects and constructed a social benefit evaluation system for major power transmission and transformation projects [4]. Zhang Wang et al. (2019) conducted a comprehensive evaluation of the construction benefits of power transmission and transformation projects from four aspects: technical benefits, economic benefits, social benefits, and sustainable development [5]. Huang Yikang et al. (2020) constructed a judgment matrix based on expert opinions, taking into account factors such as construction techniques, environmental impact factors, and policy regulatory requirements of power transmission and transformation projects. They then employed the AHP (Analytic Hierarchy Process) model to quantitatively analyze green evaluation indicators during the construction phase [6]. Li Ming et al. (2021) analyzed factors affecting risky operations from four aspects: personnel, equipment, environment, and management, and established a multi-level safety risk evaluation index system. By utilizing the Analytic Hierarchy Process (AHP), they developed a systematic risk assessment model [7]. Tang Botao et al. (2023) believe that the cost factors affecting power grid overhaul projects mainly include design factors, technical factors, construction factors, equipment and materials, environmental factors, and operational inputs [8].

In response to the evolving external environment of the construction of power transmission and transformation engineering and the development needs for lean management in power grid enterprises, this paper establishes an evaluation index system for benchmark smart construction sites of power transmission and transformation projects, focusing on the dimensions of professional management and methodologies. Additionally, it examines methods for calculating index weights and comprehensive evaluation scores to support the entire process of power transmission and transformation engineering within power grid enterprises.

2 Setting of Evaluation Indicators for Benchmark Smart Construction Sites of Power Transmission and Transformation Projects

A smart construction site refers to optimizing various stages throughout the entire process of power transmission and transformation engineering construction through information technology. It involves data mining and analysis at each stage to provide trend analyses and response plans, establishing an information-based ecosystem for construction projects characterized by interconnected collaboration, intelligent production, and scientific management. This approach enables intelligent management of power transmission and transformation engineering construction. Taking into comprehensive consideration the characteristics of smart construction sites for power transmission and transformation engineering, we have established an indicator system for evaluating benchmark projects across two dimensions: professional management and methodologies. Under professional management, we evaluate aspects such as quality, safety, design, progress, environmental protection and water conservation, and construction cost. For methodologies, we assess aspects like standardization, green transformation, mechanization, and intelligence.

In the dimension of professional management, we emphasize the concept of lean management in response to the current challenges faced in infrastructure management. By refining the granularity of professional management, we strengthen the control of information technology over key aspects such as project quality, safety, design, progress, environmental and water conservation, and cost. We continuously enhance both the horizontal cohesion of professional systems and the vertical penetration of professional management, thereby driving the management capability of benchmark projects to a new level. In terms of quality management, the primary focus is on evaluating the utilization of intelligent means to support physical quality management and the management of physical inspection projects, as well as assessing the application of information technology in recording quality documents. For safety management, the evaluation primarily concerns the effectiveness of information technology in supporting whole-process risk control, the implementation of safety enforcement measures, and the reduction of safety risks, along with assessing how information technology assists responsible personnel in fulfilling their duties. In terms of design management, the primary focus is on evaluating the effectiveness of utilizing information technology to carry out design planning, avoid major design changes, enhance the depth of design for special environments, and adopt recommended technological achievements. For progress management, the evaluation primarily concerns the effectiveness of information technology in supporting the execution of milestone plans and ensuring that key tasks are carried out according to prescribed processes. In terms of environmental protection and water conservation management, the primary focus is on evaluating the application of information technology in aspects such as environmental and water conservation construction design, system formulation, organizational management, implementation of key measures, and acceptance quality. For construction cost management, the evaluation primarily concerns the digitization level of budgetary estimates and budget management, cost adjustments, and divisional settlements.

In the dimension of professional management and methodologies, standardization, green transformation, mechanization, and intelligence serve as the new productive forces in the field of engineering construction. The core objective is to drive the high-quality development of engineering construction by pursuing higher value, adopting newer methods and means, and achieving superior quality and efficiency. In terms of standardized construction, it mainly evaluates the application of general design, general equipment, standard technology, etc. In terms of green construction, the implementation of green planning, green design, green construction, green handover and other requirements is mainly evaluated. In terms of mechanized construction, the application of mechanized construction, substation integration equipment, and prefabricated assembly technology is mainly evaluated. In terms of intelligent construction, the data quality of key nodes of the project and the application of the engineering intelligent system are mainly evaluated.

Based on the above analysis, an evaluation indicator system for benchmark projects of smart construction sites in power transmission and transformation engineering is formed, as shown in Table 1.

Table 1. Evaluation indicator System for Benchmark Projects of Smart Construction Sites in Power Transmission and Transformation Engineering

Primary indicators	Secondary indicators	Tertiary indicator	weight
Profes-sional Manage-ment	Quality	Informatization coverage of engineering quality management	0.05
		Engineering quality inspection specification rate	0.04
		Quality document specification rate	0.02
	Safety	Informatization coverage of risk management and control	0.04
		Informatization coverage of security enforcement measures	0.02
		Pressure drop rate for security risks	0.03
	Design	Informatization coverage of design and planning	0.02
		Significant design change rate	0.04
		Design depth specification rate for special environ-ments	0.04

		The application rate of applied technological achievements	0.03
	Progress	Milestone plan implementation informatization coverage	0.05
		Specify the standard rate of process implementation	0.05
	Environmental Protection and Water Conservation	Informatization coverage of environmental protection and water conservation construction design	0.03
		Standardization rate of environmental protection and water conservation documents	0.02
		The implementation rate of key measures for environmental protection and water conservation	0.03
	Construction Cost	Rate of deviation between budget estimates and budgets	0.04
		Design change and on-site visa norm rate	0.03
		Segment settlement implementation rate	0.02
Methodology	Standardization	Universal design adoption rate	0.02
		General device adoption rate	0.02
		Standard process application rate	0.02
	Green Transformation	Green planning norm rate	0.03
		Green design norm rate	0.04
		Green construction specification rate	0.04
		Green handover norm rate	0.03
	Mechanization	Mechanized construction rate	0.04
		Integrated device adoption rate	0.04
		Application rate of prefabricated assembly technology	0.04
	Intelligence	Data collection rate of key nodes	0.04
		Intelligent system adoption rate	0.04

Among them, risk management and control refers to a series of measures taken during construction activities to reduce potential safety risks, thereby reducing the likelihood of accidents and the losses caused by them. Significant design changes refer to significant modifications or adjustments made to the engineering design scheme, scale, standards, and other principles and opinions determined by the preliminary design review during the design phase of an engineering project. Special environmental design depth refers to the depth of environmental factors and design requirements that need to be considered in engineering design under special or extreme conditions to ensure the safety and reliability of the project. Design change refers to the modification, revision, optimization, or improvement of the design standard status of the original construction drawings during the construction process of an engineering project. On site visa refers to a certification document jointly signed by the on-site representative of the contracting party and the on-site representative of the contractor in case of additional construction content or cost increase due to design changes or other reasons during the construction process. Segment settlement refers to a settlement method in which each division of a project is settled separately in an engineering project. Universal design refers to engineering construction design that can be used by everyone without the need for improvement or special design. General device refers to widely used and versatile production equipment. Standard process refers to the process of operating according to certain standards and specifications during the production process. Green design refers to the design concept that fully considers environmental protection and resource conservation in the process of product design, manufacturing, and use. Mechanized construction refers to a construction method that utilizes mechanical equipment for engineering construction.

The informatization coverage rate = the number of projects or links using informatization means / the total number of projects or links, the specification rate = the number of projects or documents that meet the requirements of the specification / the total number of projects or documents, the pressure drop rate = the number of pressure drop risks / the total number of risks, the change rate = the number of design changes / the total number of designs, the application rate = the number of technical achievements used / the number of recommended technical achievements, the implementation rate = the number of measures implemented / the total number of measures implemented by the regulations, the deviation rate = the actual deviation amount / the total planned amount, Data collection rate = Number of key nodes for data collection/Total number of key nodes.

Set the evaluation indicator score = indicator value×100. The total evaluation score is set to 100, which is calculated by the weighted average of the evaluation scores of each indicator.

3 Calculation of Indicator Weights for Benchmarking Smart Construction Sites in Power Transmission and Transformation Engineering

The basic principle of the Analytic Hierarchy Process (AHP) is to analyze a problem by examining its influencing factors, internal connections, and external manifestations. This process involves breaking down a complex goal into simpler, measurable indicators and parameters. Based on the relationships and importance of these indicators, a judgment matrix is created for each level and element, allowing for the calculation of weight values for the overall hierarchy based on the significance of each element relative to the target level. AHP is useful in situations with uncertainty and subjective information, as it incorporates experience, insight, and intuition. Additionally, it employs a hierarchical structure that facilitates the analysis and measurement of the importance of indicators in relation to the target level.

The first step involves establishing a hierarchical structure model. This is accomplished by thoroughly analyzing the actual problem and subsequently breaking down the indicators into multiple levels. Factors within the same level are both subordinate to those at a higher level and exert influence on those at a lower level. In this context, the hierarchical structure model directly aligns with the evaluation indicator system for each management attribute, thereby obviating the need for the creation of a distinct, separate model.

The second step is to construct a judgment matrix. Starting from the second level of the hierarchical structure model, for each factor at the same level that is subordinate to (or influences) a factor at the previous level, a judgment matrix is constructed using the pairwise comparison method, continuing until the final level.

The third step is to calculate the weight vector and perform a consistency check. For each judgment matrix, calculate the maximum eigenvalue and its corresponding eigenvector, and then use the consistency index, random consistency index, and consistency ratio to perform a consistency check. If the check passes, the normalized eigenvector is used as the weight vector; if it fails, reconsideration should be given to reconstructing the judgment matrix.

The fourth step is to determine the comprehensive weight of each indicator. According to the weight of each group of indicators belonging to an indicator in the upper layer, the weight of the lowest index relative to the overall goal is calculated by calculating the composite weight layer by layer from top to bottom, so as to determine the weight of each decomposition index.

Solicit scores from infrastructure management experts and calculate the weight of each indicator based on the AHP. The weights of each indicator are presented in Table1.

Taking Project A as an example, the scores of its various indicators can be calculated, and its comprehensive score can be calculated as 88.36 through weights. Among them, The scores of indicators such as informationization coverage of engineering quality management, informationization coverage of risk management and control, informationization coverage of security enforcement measures, informationization coverage of design and planning, informationization coverage of environmental protection and water conservation construction design, rate of deviation between budget estimates and budgets, and data collection rate of key nodes are below 85 and require special attention.

4 Conclusion

Accelerating the construction of power transmission and transformation projects and creating benchmark projects for modern smart construction sites are important measures for power grid enterprises to serve economic and social development and improve power supply quality. This article integrates information technology and engineering management to set evaluation indicators, innovating the method of benchmark engineering indicator management. This article studies the ability to more accurately measure the benchmark construction level of modern smart construction sites in substation engineering under the background of digital transformation of power grid infrastructure, better assist management personnel in project selection, and better help each project clarify improvement directions.

In the future, it can be considered to use an indicator system for benchmark project selection, establish a machine learning model based on the selection results, quantitatively analyze the key management factors that affect the effectiveness of benchmark project construction, and propose improvement strategies from the perspective of engineering management. Supervised machine learning models can be used to calculate indicator weights based on accumulated data, avoiding the influence of subjective judgments by experts.

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