



Research on Performance Appraisal Indicators of Construction Engineering Projects from a Digital Perspective

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Abstract. Against the backdrop of the digital transformation and upgrading of enterprise management, with the development of digital technologies such as big data, 5G, cloud computing, the Internet of Things (IoT), and BIM, the performance evaluation of engineering projects is gradually advancing towards digitalization and intelligence. Performance appraisal indicators are a key element in the process of digital transformation and upgrading of engineering project performance evaluation. This paper focuses on the performance appraisal indicators during the construction phase of engineering projects. From the perspective of digital transformation and upgrading, it analyzes the necessity and challenges of refining performance appraisal indicators, and proposes corresponding solutions to further promote the digital and intelligent transformation and upgrading of engineering project performance evaluation.

Keywords: Digitization; Engineering Projects; Performance Appraisal Indicators; Refinement

1 Introduction

With the in-depth advancement of the new round of technological revolution and industrial transformation, digital technologies such as big data, 5G, cloud computing, IoT, and BIM are developing rapidly, making digital transformation and upgrading an irresistible trend. The national "14th Five-Year Plan for Digital Economy Development" clearly puts forward the goal of digital development: by 2025, the ability of digital innovation to lead development will be greatly enhanced, the level of intelligence will be significantly improved, and remarkable achievements will be made in the integration of digital technology and the real economy. The construction industry is an important pillar industry for national economic development. Along with the rapid development of digital technology, engineering project management is also undergoing rapid digital transformation and upgrading, and the digital application of engineering project performance evaluation has become increasingly widespread.

However, due to the insufficient refinement of traditional engineering project performance appraisal indicators, it brings challenges to the digital transformation and upgrading of engineering project performance evaluation.

2 Necessity of Refining Engineering Project Performance Appraisal Indicators from a Digital Perspective

The refinement of performance appraisal indicators is the foundation for the digitalization of performance management. The digital strategy has been elevated to a national strategy, and all industries are undergoing digital transformation and upgrading. It is also an inevitable trend for engineering project management to move towards digital transformation and upgrading. At the same time, through digital transformation and upgrading, enterprises can improve their management level and achieve high-quality development. Performance management is an important starting point for enterprises to realize high-quality development. As the core content of performance management, a refined performance appraisal indicator system is the foundation for realizing the digital transformation and upgrading of performance management.

(1) Digital Transformation and Upgrading of Engineering Project Management is an Inevitable Trend

The digital strategy has been elevated to the national strategic level in China, and the digital transformation and upgrading of engineering project management is an inevitable trend. The "Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through the Year 2035" proposes to comprehensively drive the transformation of production methods, lifestyles, and governance methods through digital transformation, and deepen the digital application of operation and management. The "14th Five-Year Plan for National Informatization" proposes to comprehensively improve enterprises' digital capabilities, accelerate the development and promotion of enterprise digital capability standard systems; build digital transformation methodologies and digital transformation standard systems around enterprise digital capability construction; and focus on the development of digital capabilities such as product innovation, production and operation management and control, user services, ecological cooperation, employee empowerment, and data development. The "14th Five-Year Plan for the Development of the Construction Industry" proposes to greatly improve the level of industrialization, digitalization, and intelligence of the construction industry, and consolidate the foundation of standardization and digitalization.

(2) Traditional Performance Management Informatization Has Certain Limitations in Improving Enterprise Management Capabilities

The traditional enterprise management information system replaces manual operations through information technology on the basis of manual work, thereby improving work efficiency, but it has great limitations in improving enterprise management levels.^[1] The traditional information system transplants the enterprise's inherent business processes to the information system, which is the solidification of the enterprise's inherent management concepts, management systems, and business processes. The

operation efficiency of the information system depends on the enterprise's comprehensive management level. For example, the traditional engineering project performance appraisal system is designed based on the inherent performance appraisal system and processes of engineering projects, which realizes the manual performance appraisal mode through information technology. Performance indicators and performance data are input manually. The information system mainly undertakes the function of statistical analysis. Although work efficiency is improved, there are certain limitations in improving enterprise management levels.

(3) Digital Performance Management System Can Promote the Improvement of Enterprise Performance Management Levels

The digital performance management system integrates advanced performance management concepts, theories, methods, and tools into the modern digital management information system, surpasses the enterprise's inherent performance management level, and reversely promotes the upgrading of the enterprise's performance management level. Based on the refined management of organizations, positions, goals, plans, and budgets, the digital performance management system completes the collection, analysis, and evaluation of performance data. The system integrates scientific modern performance management concepts and tools, and integrates the standards and evaluation methods of various refined performance indicators such as organizations, positions, goals, plans, and budgets. Managers only need to select corresponding indicators according to the performance appraisal requirements to obtain the corresponding performance appraisal results. For example, for the safety management indicators of engineering projects, starting from the first-level indicators of the project department, the digital performance appraisal system refines the sub-project indicators, sub-sub-project indicators, and sub-item indicators, and configures corresponding forms. Safety officers at all levels carry out work according to relevant forms. Safety supervisors at all levels can observe the work process and results of safety officers through the system, and can conduct real-time performance appraisal and communication with safety officers, which greatly improves the scientificity, accuracy, and efficiency of performance appraisal.

(4) The Refinement of Performance Appraisal Indicators is the Foundation of Digital Performance Appraisal Management

To realize digital performance appraisal, it is necessary to conduct refined management of performance indicators and performance data, minimize human participation in performance indicators and performance data, thereby reducing the cost of performance appraisal and improving the efficiency and accuracy of performance appraisal. By refining performance indicators to the smallest granularity and enabling terminal data collection, manual data input is reduced, and the error rate and repeated data input work are lowered.

3 Challenges of Engineering Project Performance Appraisal Indicators from a Digital Perspective

With the development of technologies such as BIM, cloud computing, big data, IoT, mobile technology, intelligent devices, 3S technology, and 3R technology, the digitalization and intelligence of engineering project management are in full swing. Especially, smart construction sites based on BIM technology have been widely promoted in engineering project management. Smart construction sites apply technologies such as BIM, IoT, 3S, and 3R to project management, focusing on collecting relevant production data through information technology, analyzing, processing, and presenting the data to provide support or intelligent decision-making for project management. However, the establishment of data collection and analysis models for smart construction site systems needs to be based on the refined management of enterprise engineering projects. In terms of the digital upgrading of engineering project performance management, enterprises also face challenges in terms of performance management capabilities and the refinement of performance appraisal indicators.

(1) Enterprise Performance Management Capabilities Restrict Digital Transformation and Upgrading

In terms of enterprise performance management capabilities, some large and medium-sized enterprises have professional human resources talents, and their performance management capabilities are relatively strong, which can basically provide professional support for the digital upgrading of performance management. However, most small and medium-sized enterprises are lacking in professional human resources talents and have insufficient capabilities, so their performance management capabilities are relatively weak, and the professional support provided for the digital upgrading of performance management is limited. Moreover, in the process of enterprise digital transformation and upgrading, digital professional and technical teams are mostly the leading force, but the digital professional and technical teams have limited professional knowledge and capabilities in performance management. The development of digital management systems relies more on enterprise managers' understanding and description of the management status and management upgrading needs. This leads to the continuous attenuation of the description, understanding, and realization of digital performance management upgrading needs, making it difficult to develop a digital system that promotes the upgrading of enterprise performance management levels.

(2) Insufficient Refinement of Engineering Project Performance Indicators

The performance appraisal indicators of engineering projects are constructed from four aspects: finance, customers, internal operations, and learning and growth based on the Balanced Scorecard tool. However, the refinement of performance indicators is insufficient, and the performance indicators are not decomposed to the end of the business. Performance data is still completed manually, so the functions of the digital system cannot be fully and effectively exerted. For example, the performance data of safety management indicators should come from the collection of safety data of sub-item projects. The safety management performance data of sub-projects and sub-sub-projects are all derived from the statistics and merging of safety management perfor-

mance data of sub-item projects. However, due to the failure to effectively decompose performance indicators to sub-item projects, it is necessary to manually count and input relevant data at the sub-project or sub-sub-project level, which greatly reduces the validity and accuracy of the data.^[2]

4 Solutions for Refining Engineering Project Performance Appraisal Indicators from a Digital Perspective

The refinement of performance appraisal indicators is mainly achieved through three steps: the design of the performance indicator system, the construction of the performance data system, and the refined decomposition of indicators.^[3]

(1) Construction of Engineering Project Performance Appraisal Indicator System Based on Balanced Scorecard

The design methods of performance appraisal indicators include the Balanced Scorecard method, process analysis method, and responsibility decomposition method. The performance appraisal of construction engineering projects belongs to organizational performance appraisal, which is mainly positioned to implement the strategic goals and tasks of enterprises and projects. Therefore, it is reasonable to design the performance indicator system using the Balanced Scorecard method. The Balanced Scorecard method mainly designs performance appraisal indicators from four dimensions: finance, customers, internal operations, and learning and growth. According to the project positioning and strategy, performance appraisal indicators are designed from the four dimensions of the Balanced Scorecard. Taking the construction phase of construction engineering projects as an example, the performance indicator system of construction engineering projects based on the Balanced Scorecard method is shown in Table 1:

Table 1. Performance Indicator System of Construction Engineering Projects (Taking the Construction Phase of Engineering Projects as an Example)

Financial Indicators	Customer Indicators	Internal Operation Indicators	Learning and Growth Indicators
Output Value Completion Rate	Customer Satisfaction	On-time Completion Rate of Schedule	Total Factor Productivity
Cost Control Rate	Communication and	Plan Effective Equipment Utilization	Average Employee Training
Expense Control Rate	Coordination Effect	Rate Material Waste Control	Hours Key Employee
Payment Collection Rate	Contract Term Performance Rate	Technical Standard Compliance Rate	Retention Rate Team
	Number of Complaints	Qualified Rate of Quality Inspection	Collaboration
	Owner's Claim Amount	Number of Safety Accidents	
		Number of Environmental Accidents	
		Number of Violations of Operating Procedures	

(2) Construction of Digital Base for Performance Management Based on Management by Objectives

Performance management is the main means of project management by objectives. Therefore, the digital foundation of engineering project performance management is guided by the achievement of project objectives.^[4] Through the digital system, it

collects the performance data of the formulation, decomposition, implementation, and results of project plans, and processes and presents the data, so as to realize real-time monitoring and evaluation of the entire performance process of the project and ensure the achievement of project objectives. Therefore, the scientific design of the data system for the project implementation process and results is the top priority of project performance management.

According to the value chain of construction engineering project management, the data system is built from three operational stages: resource input, engineering construction, and project delivery, and two management modules: basic management and risk control. Based on five major data systems, namely business objectives, production and operation, resource utilization, risk control, and basic management, the digital system for engineering project performance management is constructed. The business objective data system is used to collect data such as output value, payment collection, cost, expense, and profit; the production and operation data system is used to collect data such as schedule, quality, technology, information, and customers; the resource utilization data system is used to collect data such as materials, equipment, and labor services; the risk control data system is used to collect data such as safety and environment; the basic management data system is used to collect data such as organizations/positions, personnel, systems, and processes. The five major data systems support the operation of the project digital performance management system.

(3) Engineering Project Performance Appraisal Indicators Based on Refinement

Digital performance management first needs to consider the collection of original performance data by the performance management system to form an original database, and real-time monitoring and presentation of performance process data through the performance management system.^[5] This requires minimizing the data collection granularity, that is, conducting refined data collection. To achieve refined collection of performance data, it is necessary to conduct refined decomposition of performance indicators, that is, each indicator is decomposed as much as possible until it cannot be decomposed, and it can meet the collection of original performance data. For example, for the "Output Value" indicator, the first-level indicator of the project department is "Project Output Value", which is then decomposed level by level into "Sub-project Output Value", "Sub-sub-project Output Value", "Sub-item Project Output Value", etc., until decomposed to the smallest project unit where data can be collected; another example is the "Number of Safety Accidents" indicator, the first-level indicator of the project department is "Number of Safety Accidents", which is then decomposed level by level into "Number of Safety Accidents in Sub-projects", "Number of Safety Accidents in Sub-sub-projects", "Number of Safety Accidents in Sub-item Projects", etc., until decomposed to the smallest project unit where data can be collected.^[6]

Table 2. Refined Decomposition of Performance Indicators (Taking "Output Value" and "Number of Safety Accidents" in the Construction Phase of Engineering Projects as Examples)

Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Data Source (Collectible)	Data Source (Collectible)
Project Department Indicators(Level 1 Indicators)	Project Department Indicators(Level 1 Indicators)	Sub-project Indicators(Level 2 Indicators)	Sub-project Indicators(Level 2 Indicators)	Sub-sub-project Indicators(Level 3 Indicators)	Sub-sub-project Indicators(Level 3 Indicators)	Sub-item Indicators(Final Indicators)	Sub-item Indicators(Final Indicators)
Code	Performance Indicator	Code	Performance Indicator	Code	Performance Indicator	Code	Performance Indicator
CZ	Output Value	CZ01	Foundation Engineering Output Value	CZ01-A	Unsupported Earthwork Engineering Output Value	CZ01-A-001	Earth Excavation Engineering Output Value
						CZ01-A-002	Earth Backfilling Engineering Output Value
						
				CZ01-B	Supported Earthwork Engineering Output Value	CZ01-B-001	Secant Pile Engineering Output Value
						CZ01-B-002	Foundation Pit Internal Setting Engineering Output Value
						
				CZ01-C	Pile Foundation Engineering Output Value	
		CZ02	Main Structure Engineering Output Value			
						
AQ	Number of Safety Accidents	AQ01	Number of Safety Accidents in Foundation Engineering	AQ01-A	Number of Safety Accidents in Unsupported Earthwork Engineering	AQ01-A-001	Number of Safety Accidents in Earth Excavation Engineering
						AQ01-A-002	Number of

Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Aggregated Data (Combined from Original Data)	Data Source (Collectible)	Data Source (Collectible)
							Safety Accidents in Earth Backfilling Engineering
						
				AQ01-B	Number of Safety Accidents in Supported Earthwork Engineering	AQ01-B-001	Number of Safety Accidents in Secant Pile Engineering
						AQ01-B-002	Number of Safety Accidents in Foundation Pit Internal Setting Engineering
						
				AQ01-C	Number of Safety Accidents in Pile Foundation Engineering	
		AQ02	Number of Safety Accidents in Main Structure Engineering			
						

5 Conclusion

In summary, from the perspective of digital transformation and upgrading, through the analysis of the four dimensions of the Balanced Scorecard and the value chain of engineering project management, a goal-oriented performance indicator system is established, and the performance indicators are refined and decomposed. This lays the foundation for the digital transformation and upgrading of engineering project performance appraisal and is of great significance for improving the refined management of engineering projects.

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