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Digital Twin in the EPC Project Contracting Mode

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Abstract. This study focuses on the cost control of construction projects under the general engineering contracting mode based on digital twin technology. Through the centralized procurement of Internet of Things, cloud computing, transportation, and storage optimization, and the digital management of bill of quantities, it is found that it can effectively optimize the procurement cost and reduce the loss. Combined with the actual project, the comprehensive unit price and total price differences of labor cost, material cost, and machinery cost under the optimization of digital twin technology are compared and analyzed, and the key influencing factors and optimization path are revealed. The study further proposes a dynamic monitoring mechanism. At the same time, based on the characteristics of the general engineering contracting (EPC) mode, it is suggested to strengthen the connection between pre-planning, process monitoring, and completion settlement from the whole process of design procurement, construction, big data cost control management, so as to improve the coordination efficiency. The case analysis shows that the EPC contracting mode can reduce the comprehensive cost by 10% -15% by integrating resources and optimizing the supply chain through digital twin technology, providing theoretical and practical support for construction enterprises to maximize economic benefits. The research results have reference value for improving the EPC project system and enhancing the anti-risk ability of the industry.

Keywords: EPC Turnkey Model, Construction Engineering, Digital Twin, Project Management

1. Introduction

With the acceleration of urbanization and the continuous expansion of infrastructure investment, China's construction engineering field is facing the dual challenges of efficiency improvement and cost optimization. Under the traditional contracting mode, the separation of design, procurement, and construction leads to the waste of resources and the delay of the construction period. In this context, EPC mode has gradually become the core mode of modern engineering management by virtue of its integrated advantages of "design procurement construction" integration. EPC mode significantly reduces project complexity and coordination cost by coordinating the whole process tasks to a single responsible entity, while improving construction quality and resource utilization. This model not only responds to the national policy guidance of "cost reduction and efficiency

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increase" but also becomes an important way for construction enterprises to cope with market competition and realize supply chain synergy.

However, the complex supply chain structure and dynamic cost characteristics of the EPC mode put forward higher requirements for cost control. The proportion of material cost and labor cost in an EPC project is as high as 60%-75%, which is affected by both internal and external factors. Procurement strategy deviation, logistics management inefficiency, and other problems occur frequently. The fluctuation of international raw material prices and the tightening of environmental protection policies, such as the increased compliance costs of carbon emissions trading, further exacerbate the cost uncertainty. In addition, EPC projects often face the pressure of capital turnover and the risk of supply chain disruption, resulting in the project's dynamic cost deviating from the initial budget.

By analyzing the optimization of cost control under EPC mode, this study aims to deepen the understanding of digital twin technology on the formation law of the dynamic cost of EPC projects and improve the theoretical framework of supply chain cost control. At the practical level, it provides operable cost reduction strategies for construction enterprises to help them improve their profitability and risk management ability in a complex market environment.

Focusing on the cost control under the EPC contracting mode as the core theme, taking the Hongxing Jiannan block well area evaluation and construction purification station (EPC) project as the empirical object, this paper reveals the proportion law of labor cost, material cost, machinery cost and other cost elements, and explores the cost control path through key links such as digital twin technology design optimization, procurement strategy, dynamic monitoring and so on. Promote the formation of a digital twin horizontal alliance from the perspective of labor, materials, and equipment, and optimize the cohesion in project management.

This study uses the case analysis method to compare the cost data of the two contracting modes of the purification station project in the well area of Hongxing Jiannan block, and to quantify the cost reduction effect of digital twins. This paper aims to clarify the core influencing factors and mechanisms of cost under the EPC mode, and puts forward the whole life cycle cost control strategy of using digital twin technology to cover "early planning process monitoring completion settlement".

2. Digital twin theory

2.1. Elements and connotation of digital twins

M W. Grieves of the University of Michigan first proposed the concept of "digital twins" in 2003 Digital twin is a special physical entity or program, which is realized through a data link, ensuring the consistency between the entity and virtual state to a certain extent. Digital twin emphasizes the connection with a physical entity, while Building Information Model(BIM) does not emphasize the connection with a physical entity [1]. And it can provide a complete perspective for the whole life of the entity or process, so as to help realize the overall performance optimization [2]. Digital twin is a virtual entity that uses digital means to establish physical entities, and uses algorithm models, historical data, and real-time data. It is the key technology for digital governance to change towards a more reasonable and intelligent direction [3]. Professor Grieves proposed a three-dimensional feature model based on the connection of physical entities and virtual entities for digital twin technology [4]. On this basis, Taofei et al. proposed a five-dimensional element model of digital twin technology, adding two dimensions of twin data and service [5].

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2.2. Theoretical framework of digital twinning under EPC mode

EPC mode realizes risk sharing through a total price contract, and its cost control presents three characteristics: more than 70% of the project cost is determined in the design stage, and the function cost needs to be optimized through value engineering. The lock-in effect of early decision-making on the project economy requires the contractor to establish a full life cycle cost awareness at the design stage. Digital twin is user-oriented and optimizes the contracting mode through functional system analysis. Explore the deep integration path of BIM Technology and big data collaboration in EPC mode, and use digital twin technology in the whole process of EPC "design procurement construction".

In the design stage, through the investigation of the Shenzhen China Corridor Project, Beijing Xiong'an expressway project and other projects, the application scenarios of digital twin technology in the design stage mainly include: design scheme demonstration, investment estimation, general drawing planning, engineering quantity accounting and output, collaborative design of various disciplines, collision inspection [6, 7]. In these application scenarios, the characteristics of 3D model visualization and high-precision simulation of physical entities can be brought into full play, which can save a lot of personnel investment and time cost, improve the work efficiency in the design stage, and at the same time, the automatic output of data and collaborative design provide data guarantee for the work in the subsequent stages.

In the procurement phase, increasing the proportion of centralized procurement can shorten the procurement cycle, and blockchain traceability technology can reduce the dispute rate. Supply chain collaboration requires the establishment of a hierarchical supplier management system to achieve transparency and efficiency in the procurement process through dynamic pricing and full traceability mechanisms. The essence is to reduce transaction costs and uncertainty through resource integration and process optimization [8].

In the construction stage, the construction stage is the stage with many application scenarios of digital twin technology at present. At this stage, with the gradual progress of the construction of the physical road project, the five-dimensional technical elements of the digital twin are gradually completed, laying the foundation for the overall implementation and application of digital twin technology. In the process of construction management, the physical entity is digitally simulated to generate a dynamic twin digital scene. In this scenario, not only can physical entities be simulated in space, but also cameras, IoT sensors, and other devices can be added to build a digital twin model. For the management of the whole process of construction, a unified information and data management platform is established. Around personnel, equipment, materials, quality, environmental protection, safety, and other aspects, through high-precision intelligent sensing devices and algorithms, an information ecosystem of interconnection and collaboration, intelligent production, and decision-making assistance is built [9]. Intelligent monitoring and decision-making are carried out for the project construction, so that the project construction can realize intelligent management. At present, the application of digital twin technology in the construction stage is mainly reflected in two areas: smart construction sites and smart construction.

3. Analysis of digital twins

3.1. Research on the application of digital twin technology in a single project under EPC mode

Combined with the cost optimization rate of this research project, under the condition that there is no obvious difference in the variance of the index mark, calculate the comprehensive unit price of

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labor cost, material cost, machinery cost and other items of the EPC project of the purification station in the well area of Hongxing Jiannan block under the digital twin mode, and calculate the comprehensive total price to evaluate the effect of cost control. The results are shown in Tables 1 and 2. It can be seen that the labor and material costs account for a relatively high proportion in the comprehensive unit prices of the project, accounting for about 30% -40% of the labor costs and about 60% of the material costs. With the optimization of the contracting mode, the cost proportion of various expenses has been continuously reduced, and the cost of the comprehensive unit price has also been continuously reduced.

Table 1. Project investment estimate

Title	Cost(ten thousand CNY)
Engineering Costs	17,206.00
Equipment and Material Costs	10194.00
Construction and Installation Costs	7012.00
Other Costs	3270.00
Management Fee	2480.00
Survey and Design Fee	732.00
Engineering Insurance Fee	57.00
Contingency	2047.00
Total	22525.00

Table 2. Project investment estimate

Title	Cost(ten thousand CNY)
Direct Expense	13,558.87
Equipment and Material Costs	8432.28
Construction Costs	1316.43
Sun-Contractor Costs	1295.90
Support service in Warranty Period	250.00
Pre-commissioning and Commissioning	345.90
Temporary Facility (Camp, Warehouse)	950.00
Other Construction Miscellaneous	968.36
Indirect Expense	2,113.59
Management Costs	1288.94
Mobilization and demobilization Costs	55.81
Camp Construction Costs	54.86
Camp Operation Costs	257.05
Financial Costs, Insurance, and Taxes	456.93
Other Fees	1540.21
Company Management	800.00
Engineering Service	686.99
Project Insurance	53.22

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Table 2. (continued)

Contingency Fee	1721.27
Total	18933.93

It can be seen from Table 2 that among the projects applying digital twin technology, the cost control effect of material cost is the most prominent. This shows that under the EPC general contracting mode, with the help of the digital twin system, the dynamic simulation and multi-scheme comparison of material and equipment schemes can be carried out, so as to select materials with higher cost performance, and realize centralized procurement and transportation path optimization through virtual procurement and logistics simulation, significantly reducing the procurement and storage costs. Digital twin technology can also use the information management platform to retrieve real-time data and analyze the data through real-time sensing of material entry, use, and inventory status, and carry out real-time early warning and data analysis through the system to accurately locate and quickly respond [10]. In addition, the system can automatically check the matching degree between the bill of quantities and the contract terms, assist in identifying the potential change and claim risk in the subcontracting project, and strengthen the transparent monitoring of the professional subcontracting process, so as to control the subcontracting cost more accurately. The real-time feedback and visual management of project cost are realized through the digital twin platform, which can actively identify the deviation and trigger the correction mechanism, laying the foundation for the establishment and integration of an intelligent system of the whole life cycle and the whole process elements in the future [11].

3.2. Internal and external factors affecting the optimization of digital twin technology and countermeasures

At present, through the construction practice of smart construction sites in recent years, most construction units believe that through digital twin technology, the elements of each link of the EPC project can be known, measurable, and controllable, thus greatly reducing the overall cost of the project. It can not only reduce the energy consumption of the project, avoid environmental pollution, but also ensure the safety of construction, and improve the ability to deal with and control accidents [12]. However, there are also the following problems. From an internal perspective, there is a lack of a standard specification system. At present, the construction of digital twins is mostly spontaneous, and there are great differences in the understanding of its connotation, composition, and function. In order to avoid disorderly development, the industry competent department should formulate unified standards as soon as possible. At the same time, there is a lack of overall planning for the whole life cycle of construction. Due to the overall consideration of BIM Technology in the design, construction, and later operation and maintenance stages, the application results and data obtained in the construction stage cannot run through the whole life cycle, and the value of digital twin technology is greatly reduced. From the outside, the current digital twin technology lacks the thinking of integrated development with the future transportation mode. At present, the application in smart construction sites may only promote the construction for some problems in the construction stage, without considering the use situation of the EPC "design procurement construction" whole process, which may lead to poor scalability of the existing data platform and can not be applied to the future transformation of transportation mode.

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4. Conclusion

Based on the EPC project as the background, this study discusses the application effect of digital twin technology in construction engineering, and makes an empirical analysis combined with the construction of the purification station (EPC) project in Hongxing Jiannan block. The research shows that the digital twin has realized the whole process cost visualization and preview optimization from design, procurement, to construction by constructing a virtual model synchronized with the physical engineering, which has significantly improved the coordination efficiency in complex engineering, especially in the material procurement and logistics link to achieve about 16% cost savings. By constructing the integrated framework of "digital twin + cost control management", this study defines the implementation path of the technology in the aspects of optimized design scheme, accurate procurement planning, real-time cost monitoring, etc., and provides a method to support the fine management of EPC projects. In order to give full play to the advantages of digital twin in the cost control of EPC project, it is suggested to embed the digital twin platform in the project planning stage and improve the accuracy of target cost compilation by relying on historical data and algorithm model; During the implementation process, a cost deviation early warning and automatic feedback mechanism is established through dynamic data driving to respond to the change of quantities and market price fluctuations in a timely manner. In the procurement process, virtual simulation can be used to optimize supplier selection and logistics schemes, promote the integration of centralized procurement and green supply chain, and reduce material and transportation costs. Promote it to achieve a higher level of cost transparency and management and control efficiency relying on digital twin technology, so as to enhance the market competitiveness and sustainable development ability of enterprises. With the deepening of digitalization and green transformation in the construction industry, the cost control potential of digital twin technology in EPC mode will be further released. In the future, we can combine BIM, the Internet of Things and artificial intelligence to achieve more accurate supply chain prediction and carbon footprint tracking, and build a cost control model integrating low-carbon goals. At the same time, we should actively explore the adaptability of the digital twin system in international EPC projects, study the cost dynamic adaptation strategy under cross-regional and multi-standard conditions, and promote the EPC mode to become the key driving force for the high-quality and sustainable development of the construction industry.

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