Research On the Application of Intelligent Management Technology in Construction Engineering

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Abstract. Under the background of rapid economic and urbanization, the management mode of construction engineering is undergoing a transformation to adapt to the increasing complexity and dynamic nature. With the help of modern information technology, intelligent project management provides a full-cycle solution for construction projects. This study explores the multiple applications of intelligent technology in construction project management, including the integrated application of (Building Information Modeling) BIM technology in design, construction and operation, as well as the practice of intelligent schedule management, cost control and site safety supervision. The study found that although the application of BIM technology in construction schedule management is still in its infancy, it shows great potential in improving design and construction quality and optimizing resource management. By integrating the smart site platform and the Internet of Things (IoT) technology, the intelligent progress management system realizes the real-time monitoring of the construction process and improves the accuracy and response speed of project management. In terms of cost management, the application of intelligent technology significantly improves the accuracy of cost control and management transparency through real-time monitoring, data integration and predictive optimization. At the same time, the application of smart wearable devices and image recognition technology provides new solutions for the safety management of construction sites, and improves the efficiency of worker safety and site supervision.

Keywords: Intelligent management; BIM application; real-time monitoring; cost control; safety management.

1. Introduction

With the rapid development of economy and the acceleration of urbanization, the field of construction engineering is experiencing unprecedented changes. As an important part of urban development, the quality and efficiency of construction engineering directly affect the appearance of the city and the quality of life of residents. However, the traditional construction management techniques have gradually exposed their limitations when dealing with the increasingly complex project needs and the changing market environment. These limitations are mainly manifested in the phenomenon of information island, that is, the poor flow of information, which makes it difficult to achieve effective communication and coordination in all aspects of project management [1]. Low efficiency, paper document management makes information update slow, cumbersome decision-making process, affecting the progress of the project and cost control. Inadequate risk management, the lack of systematic and forward-looking identification of potential risks and formulation of countermeasures increase the risk of project failure [2]. As for resource waste, due to the lack of accurate resource allocation and management, the waste of materials, manpower and other resources is serious [3]. In order to solve the above problems, intelligent project management technology has emerged. This technology manages the full life cycle of construction projects by integrating advanced information technologies, such as the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI), so as to realize information sharing and real-time updating, and improve communication efficiency. It also provides automated decision support, utilizing data analysis and prediction models to provide scientific decision support for project management. In addition, intelligent project management technology can provide early identification and early warning of potential risks, formulate effective response strategies, and enhance risk control capabilities. It also contributes to the

optimal allocation of resources, accurately calculates and allocates resources, reduces waste, and improves resource utilization efficiency.

Based on this, this paper will study the application of intelligentized engineering management technology in the field of construction engineering. Firstly, it explores the specific application cases of intelligent engineering management technology in construction engineering and analyzes its practical application in depth. Secondly, it assesses and discusses the advantages and challenges brought by the application of intelligent engineering management technology. Subsequently, the importance of the conclusion section is demonstrated by summarizing the key points and findings, and the future research directions and development prospects are outlooked. Finally, it looks at the future development trend of intelligent project management technology.

2. Intelligent Engineering Management Technology

2.1. Building Information Modeling (BIM) Technology

BIM technology is a digital technology applied to engineering design, construction, and management, which supports the life-cycle management of buildings through the creation and use of digital information models. The core of BIM technology is its ability to provide a database containing the physical and functional characteristics of buildings, which can support the integration and utilization of information from design, construction to operation. The core of BIM technology is its ability to provide a database of the physical and functional characteristics of a building, which can support the integration and utilization of information throughout the entire process from design, construction to operation.

2.1.1 The origin and development of BIM

The origin of BIM technology can be traced back to the 1960s, when researchers began exploring the use of digital means to improve the management efficiency of construction projects. in the 1990s, with the advancement of computer technology, BIM technology began to receive more attention. the launch of Autodesk's Revit software in 2002 was an important milestone in the commercialization of BIM technology. Subsequently, BIM technology has been promoted globally, especially in the U.S. Through the promotion of the government and industry associations, the application of BIM technology in the construction industry has gradually become a standard. In China, although BIM technology started late, it has developed rapidly in recent years and has been applied in some landmark projects. The development of BIM technology has not only changed the traditional working mode of the construction industry, but also promoted the concept of total life cycle management of construction projects, realizing the integration and sharing of information in all stages of design, construction, and operation [4].

2.1.2 Current status of BIM applications

Currently, the application of BIM technology has become the core content of informationization in the construction industry, which supports the management of the whole life cycle of planning, design, construction and operation of buildings through the creation and use of digital information models [4]. In project schedule management, the application of BIM technology is still in its infancy, especially in the construction phase where the research and application are still immature. Although BIM technology is believed to significantly improve project management, the current research and application cases are relatively few and have limitations that do not fully utilize its potential value [5]. For example, the application of BIM technology in schedule management mainly focuses on 4D simulation realization, while research on other aspects is relatively lacking.

In addition, the application of BIM technology in architectural design, project construction and management also show a broad prospect. BIM technology can not only be used as a design tool, but also as an embodiment of the concept of collaborative design, which provides designers with more imagination space by creating a virtual building model containing all the features of the actual

building [6]. In the construction process, BIM technology effectively improves the construction quality and efficiency through the application of 3D collision check, engineering calculation, virtual construction and construction simulation.

2.1.3 Strengths and weaknesses

By integrating detailed information about a project, BIM technology offers significant advantages at all stages of the construction life cycle, including enhanced information sharing, improved design and construction efficiency, optimized resource management, aided schedule and cost control, and facilitated multi-party collaborative work. However, the application of BIM technology also faces some challenges, such as insufficient technological maturity, shortage of professionals, lack of unified domestic standards, and dependence on imported software systems. The application of BIM technology in construction includes key aspects such as pre-construction 3D design simulation, collision detection, and optimization of construction plans. Detailed description of the application. BIM technology plays a central role in this process by improving the efficiency and effectiveness of construction site planning through 3D simulation and virtual roaming. BIM technology improves the accuracy and efficiency of construction by creating accurate building information models that allow the project team to anticipate and resolve problems that may arise during design and construction prior to construction.

2.2. Intelligent Application of Progress Management and Real-time Monitoring Systems

Traditional schedule management methods mainly rely on manual recording and supervision, as well as the management of paper documents, which includes the use of tools such as Gantt charts, Critical Path Method (CPM), and milestone tracking to plan and monitor the progress of a project. These methods play a fundamental role in project management, but there are some drawbacks, such as untimely information update, inefficiency, error-prone, as well as difficulty in real-time monitoring and rapid response. With the development of technology, intelligent progress management systems are beginning to be widely used in construction project management. Intelligent progress management system realizes the real-time collection, integrated processing and analysis of numbers by combining the intelligent construction site platform, IoT technology, and intelligent equipment terminals, which greatly improves the real-time and accuracy of construction monitoring [1].

(1) Smart Site Platform

Smart construction site refers to the application of artificial intelligence technology on construction site management, and solves the problems of labor management, material management, safety management, environmental management and other aspects of the construction site around the construction process management. The smart construction site platform realizes accurate management of personnel and improves the efficiency and quality of construction safety management through modules such as real-name management of labor, safety education management system and labor contract management system.

(2) IoT Technology

IoT technology is effectively used in smart construction sites. By installing sensors and equipment in the project, various indicators of the project, such as temperature, humidity, energy consumption, etc., can be obtained in real time. These data, by connecting with the project management system, can automate the monitoring and feedback of the project's progress, realizing real-time monitoring and control of the construction process.

(3) Intelligent device terminals

Intelligent equipment terminals, such as AI intelligent terminal equipment, use AI algorithm models such as face recognition, helmet detection, overalls recognition, electronic fence, etc. to carry out intelligent automatic identification and report alarm information to the master station platform. These terminal devices can realize full monitoring of the construction work site and rapid identification of dangers and improve the management efficiency in multiple scenarios. The intelligent progress management system reduces the management burden by integrating and processing a large amount of construction data to form characteristic values. For example, it improves

project management efficiency through VR immersive experience safety education and training, intelligent equipment quality management, and intelligent site information management. Meanwhile, green construction technology improves the environmental benefits of the project such as energy saving, land saving, water saving and material saving.

In conclusion, the intelligent progress management system utilizes advanced technological means, such as the intelligent construction site platform, IoT technology, and intelligent equipment terminals, to achieve all-round, real-time monitoring and management of construction projects. This not only improves the real-time and accuracy of construction monitoring, but also optimizes resource allocation, reduces management costs, and enhances decision-making capabilities, thus improving the management efficiency and quality of the entire construction project.

2.3. Intelligent Cost Management

The intelligent application of cost management includes several aspects, as shown in Table 1.

Table 1. Intelligent cost management [7]

Managing projects	Methodologies	Achieved goals
Real-time cost monitoring	Utilizing sensor technology and IoT devices to collect real-time cost data from construction sites	Ensure that project managers have real-time visibility into the cost of labor, materials, equipment; make more accurate cost controls.
Cost Data Integration	Integrate all cost-related data into one system to form a comprehensive cost management system	Provides a clear view of costs, making it easy for managers to get a full picture of the project's financial status
Cost forecasting and optimization	Apply machine learning and data analytics techniques for cost prediction, and discover cost patterns through historical data learning	Achieve accurate cost forecasting and real-time early warning to help projects avoid cost overruns
Intelligent Cost Control	The system supports cost optimization and helps managers keep track of capital flows and adjust budgets in a timely manner	Reduce cost risks and improve the financial efficiency of the project
Real-time decision support	The system provides early warning and response options when construction delays or cost overruns are detected	Helps managers make quick decisions to adjust engineering plans and resource allocation
Risk prediction management	Analyze historical data to identify and assess potential risk factors and provide predictive recommendations	Help managers take early action to reduce risk
Contract and Bidding Management	Intelligent technologies are used for contract text parsing, management and bidding information analysis	Improve transparency and compliance in contract performance and optimize bidding strategies
Environmental and energy management	Reduce energy consumption and operating costs through intelligent environmental monitoring and energy management systems.	Improve the efficiency of resource utilization and indirectly enhance the overall cost-effectiveness of the project

Intelligent cost management applications greatly enhance the accuracy of cost control and the transparency of project management by integrating real-time data and utilizing advanced analytics. It enables project teams to monitor cost trends in real time, identify deviations in a timely manner, and respond quickly to market changes so that more accurate decisions can be made. In addition, the intelligent system helps optimize resource allocation through predictive analytics, reduces unnecessary expenditures, and improves overall work efficiency by reducing human errors and time delays through automated processes. Intelligent cost management also strengthens risk management. Through continuous learning and pattern recognition, the system is able to predict potential financial risks and provide early warnings, making the project more adaptable and resilient. Despite the disadvantages of higher initial investment costs and increased requirements for specialized skills, these disadvantages are expected to be mitigated as the technology matures and becomes more widespread.

2.4. Intelligent Solutions for Worker Safety and Site Management

Worker safety and site management are crucial aspects in construction sites, and with the development of technology, intelligent solutions are increasingly used in this field. The following is a detailed analysis of intelligent solutions for worker safety and site management based on the literature provided:

(1) Application of smart wearable devices

Smart wearable devices include smart bracelets, smart glasses, and motion camera devices, as shown in Fig. 1. Smart bracelets are used to track the construction workers' movement trajectories, helping managers understand the workers' positions in real time and discover potential safety problems in time. Smart glasses, on the other hand, can compare and analyze the virtual model with the actual construction situation to help workers perform construction tasks more accurately. Particle sensors on smart masks can monitor air quality, while motion camera devices are used to record the construction process and ensure the accuracy of quality acceptance. The integrated use of these devices greatly improves safety management on construction sites [8].

(a) smart glasses

(b) Smart bracelet

Fig. 1 Smart wearable devices [9, 10]

(2) Construction progress management based on BIM technology

The application of BIM technology makes the construction progress management more refined and informatized [11]. Through BIM technology, an integrated model containing data such as worker

information, construction progress and material usage can be established to realize real-time monitoring and dynamic management of the construction process. In addition, BIM technology can help project teams to more effectively allocate resources and manage risks, thus improving construction efficiency and quality.

(3) Intelligent safety inspection system for construction workers based on image recognition

A system that uses image recognition technology to improve the efficiency of safety inspection for construction workers captures the images of workers through a depth camera, and then automatically recognizes the workers' identities, safety equipment wear, and operational behavioral abilities through image processing technology. The system achieved 83.75% correct rate of identity recognition, 96.25% correct rate of helmet recognition, and 63.75% correct rate of safety belt recognition. The application of such a system not only improves the speed and accuracy of safety inspections, but also helps to reduce omissions and false inspections caused by human factors [12].

(4) Intelligent management system for construction workers integrating BIM and RFID

The system realizes real-time positioning and dynamic management of workers by equipping them with RFID tags and combining them with RFID readers at the construction site. The system architecture includes a sensing layer, a network layer and an application layer, which are responsible for information acquisition, data transmission and status analysis respectively. In addition, the system is equipped with an accident warning function and is able to visually locate and identify workers through the BIM model to improve management efficiency. The application of this integrated system not only improves the daily management of workers, but also enhances the safety management capability of the site [13].

In summary, the application of intelligent technology in construction sites provides effective solutions for worker safety and site management. The integration of intelligent wearable devices, BIM technology, image recognition technology and RFID technology not only improves the management efficiency of the construction site, but also greatly enhances the safety and security of workers. With the continuous progress and innovation of technology, future construction site management will be more intelligent and automated, bringing higher efficiency and better safety records to the construction industry.

3. Conclusion

This paper provides an in-depth discussion of the application of intelligent project management technologies in the field of construction engineering and the changes they have brought about. By analyzing BIM technology, intelligent schedule management systems, cost management, and intelligent solutions for worker safety and site management, this study draws a series of valuable conclusions.

(1) BIM technology, as the core of information technology in construction engineering, has demonstrated significant advantages in its application in the design, construction and operation phases. BIM not only improves the efficiency of design and construction, but also optimizes the management of resources, assists in schedule and cost control, and facilitates multi-party collaborative work. Although its application in construction progress management is still in its infancy, its potential should not be underestimated, and it is expected that there will be wider application and deeper integration in the future.

(2) The intelligent progress management system realizes real-time monitoring of the construction process through the intelligent construction site platform and IoT technology, which greatly improves the accuracy and responsiveness of project management. The application of such system not only enhances the real-time and accuracy of construction monitoring, but also optimizes resource allocation, reduces management costs and enhances decision-making ability.

(3) In terms of cost management, intelligent technology significantly improves the accuracy of cost control and management transparency through real-time monitoring, data integration and

forecast optimization. This enables project teams to monitor cost trends in real time, identify deviations in a timely manner, respond quickly to market changes and make more accurate decisions.

(4) The application of intelligent technology in worker safety and site management provides effective solutions for construction sites. The integration of smart wearable devices, BIM technology, image recognition technology and RFID technology not only improves construction site management efficiency, but also greatly enhances worker safety.

(5) However, there are some shortcomings in the application of intelligent project management technology, such as higher initial investment costs and increased professional skill requirements. These problems need to be solved by joint efforts within and outside the industry, through technological innovation and policy support. In the future, with the maturity and popularization of the technology, it is expected that these disadvantages will be alleviated, and the intelligent project management technology will achieve a wider application in the field of construction engineering and promote the industry to develop in the direction of higher efficiency, higher quality, and more intelligent. In summary, intelligent project management technology provides a new solution for construction project management, and although there are some challenges, with the continuous development and improvement of the technology, its advantages in enhancing the efficiency of construction project management, optimizing resource allocation, and enhancing safety and security will be more obvious. In the future, intelligent technology is expected to play a more important role in construction project management and bring revolutionary changes to the construction industry.

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