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# Research on the Integration Path of BIM and AI under the Intelligent Management Model at Construction Sites

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**Abstract:** Currently, the construction industry has largely transitioned to an intelligent management model at construction sites. Among these, the applications of Building Information Modeling (BIM) and Artificial Intelligence (AI) technologies are the most prevalent in intelligent management. The integration of these two technologies can effectively address the challenges of traditional extensive construction management and enhance the efficiency of construction site management. This article first interprets the architectural design for the integration of BIM and AI technologies under intelligent management, clarifying the mechanisms of their integration. It then focuses on analyzing the core issues in the integration of BIM and AI at construction sites and proposes innovative optimization paths for the integration of these dual technologies, guided by problem-solving, to provide references for optimizing construction site management.

**Keywords:** Construction site; Intelligent management; BIM technology; AI technology

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## 1. Introduction

The application of BIM technology in intelligent management at construction sites can transform construction process management into a visual management form and construct virtual construction models through the collection of construction data. These models can be used to analyze the standardization and controllability of various construction processes, thereby enhancing the efficiency of construction site management. However, BIM technology management tends to lean towards a static management model, unable to accurately predict construction phases and future development trends. In contrast, the application of AI technology can mine, analyze, and integrate construction data through algorithms, enabling precise and rigorous predictions of construction trends and potential risks. It is evident that the application of AI technology can effectively compensate for the deficiencies of BIM technology in construction site management, thereby optimizing the intelligent management system at construction sites [1]. However, the current applications of BIM and

AI technologies at construction sites are overly simplistic and have not formed a systematic management system, limiting the application of the integration of these dual technologies. Based on this, the article will start with the current state of dual technology integration, explore innovative integration paths, and thereby solidify the technological foundation for construction site management.

## 2. Architectural design for the integration of BIM and AI under intelligent management

### 2.1. Overall design principles and objectives for integration

The architectural design for the integration of BIM and AI technologies must adhere to corresponding principles: First, the principle of scientificity. The application of dual technology integration should be centered around the management needs of construction sites and the mechanisms of technology integration to ensure that technology integration enhances management efficiency. Second, the principle of practicality. The application of dual technology integration should effectively address management issues at construction sites and improve management efficiency, avoiding the mere formality of technology integration. Third, the principle of synergy. Dual technology integration should establish a linkage mechanism from a complementary perspective to ensure the safe and orderly conduct of construction management work. Fourth, the principle of innovation. Intelligent management at construction sites under dual technology integration should break away from the traditional fixed mode of single technology application and create an innovative intelligent management model by combining the advantages of both technologies [2]. Meanwhile, the objectives of dual technology integration application should be clarified: First, to construct an integrated construction management platform that integrates information on on-site progress, quality, safety, and cost control to break down management barriers and ensure on-site control efficiency. Second, to create a panoramic intelligent control model for construction site management to simulate construction processes, thereby enhancing on-site construction management efficiency, strengthening engineering risk prediction, and promoting the effective implementation of intelligent control mechanisms [3].

### 2.2. Construction of a multi-level technology integration architecture

The integration architecture of BIM and AI under intelligent management needs to construct a multi-level system based on management needs. First, the data layer should be constructed to lay a solid foundation for the architecture. The task of the data layer is to construct a static model of the BIM construction design plan based on engineering construction parameters. Simultaneously, AI technology should be utilized to collect various material, labor, equipment, and environmental parameters during construction, forming a dynamic data analysis model. Second, the construction of the model layer can provide a systematic and practical carrier for dual technology integration. For example, it can build a dynamic model system for the virtual model of BIM technology, which differs from traditional static models by incorporating AI technology. This model can not only automatically extract and analyze data but also automatically adjust the model structure based on the analysis results. Third, the algorithm layer is the core of the application of dual technology integration. It can clean, filter, and process data in the BIM model through AI technology and accurately manage and predict on-site progress, quality, safety, and cost based on objective data, thereby effectively avoiding construction risks [4]. Finally, the construction of the application layer can provide application ports for dual technology integration. The key to constructing this layer is to clearly and threedimensionally display the management process at construction sites and provide a management operation interface for construction managers. Additionally, the control layer can intelligently detect the control effects of dual technology models and promptly rectify unreasonable content to ensure the continuous optimization of intelligent control work. To ensure a clearer presentation of the multi-level technology integration architecture, the architecture levels, positioning, and core parameters are summarized in **Table 1** below:

**Table 1.** Multi-level technology integration architecture table

| Architecture level | Core positioning | Core parameters |
|---|---|---|
| Data Layer | Dual-technology integrated architecture foundation | Data collection accuracy ≥ 95%, data standardization rate 100% |
| Model Layer | Dual-technology integration carrier | Model accuracy level LOD400, model-site matching rate ≥ 98% |
| Algorithm Layer | Core of dual-technology control | Risk identification rate ≥ 92%, site management prediction accuracy ≥ 85% |
| Application Layer | Technical operation interface | Scene coverage rate 100% |
| Management and Control Layer | Closed-loop management and control | Hidden hazard rectification rate 100% |

### 2.3. Construction of data interoperability and sharing mechanism

The application of data interoperability in the integration of BIM and AI ensures the depth and effectiveness of the dual-technology integration, thereby addressing the issue of data silos in construction. The construction of a data interoperability mechanism can be approached from the following dimensions: Firstly, enhance data processing. Standardize data within the integrated architecture of BIM and AI technologies to ensure uniform data standards, laying the foundation for data sharing in the dual-technology integration. Secondly, establish efficient and stable data transmission channels. Utilize communication technologies such as 5G and Wi-Fi to construct data transmission channels and data storage platforms, thereby providing favorable transmission conditions for technology integration. Thirdly, optimize data sharing mechanisms. Focus on creating an integrated platform for the entire construction process management workflow to ensure transparency in construction management data. Finally, establish a dynamic data management and control mechanism. The integrated architecture of dual technologies should automatically adjust the construction site management model based on specific project conditions, ensuring alignment between the model and the actual construction site, thereby preventing management deviations [5].

## 3. Core issues in the current integration of BIM and AI on construction sites

### 3.1. Progress control: Lagging integration and inaccurate dynamic control

The application of BIM and AI integration in construction progress control on construction sites suffers from insufficient management granularity, primarily manifested in the static process models used for BIM progress management, which cannot automatically update in response to changes in construction conditions and issues [6]. Additionally, the data extraction and application in AI technology do not fully leverage its automation capabilities, with most data still requiring manual input. This results in significant lag in the integrated application of BIM and AI.

### 3.2. Quality control: Superficial application and lack of granular control

BIM and AI technologies have not yet formed a deep integration mechanism in construction site management, limiting their application to single management scenarios in quality control and making it difficult to achieve full-process control. For instance, BIM technology is primarily used for detecting design drawings and creating 3D models, struggling to provide dynamic quality tracking based on construction progress. AI technology is solely applied to the visual inspection of projects, unable to predict and prevent construction quality issues. Moreover, the effectiveness of dual-technology integration monitoring is limited, necessitating manual inspection as the core method for ensuring quality inspection efficiency, which falls short of granular control [7].

### 3.3. Safety control: Insufficient collaboration and passive risk prevention

Predicting and preventing safety risks on construction sites is challenging due to their sudden nature, requiring the development of an early warning mechanism through technology integration. However, the current application of BIM and AI integration in construction site safety control is limited. BIM technology is mainly used for simulating construction models, identifying and analyzing safety hazards from a static perspective. AI technology focuses on identifying illegal operations in construction safety control, resulting in limited synergy between the dual technologies and difficulty in accurately combining static models with dynamic identification data, leading to weak risk identification capabilities [8]. Under this integration mechanism, construction site safety management still relies primarily on post-event control, with poor preventive effects.

### 3.4. Cost control: Inefficient data and weak dynamic cost control capabilities

The application of BIM and AI integration in cost control on construction sites is limited, with significant deviations from the requirements of full-project lifecycle management. BIM technology is primarily used for project budgeting and accounting, improving calculation accuracy and efficiency. However, it cannot form a dynamic cost control mechanism based on changes in material, schedule, labor, and other dimensional elements within the project. AI technology focuses on data capture, processing, and statistics for cost control, failing to leverage its deep mining and control capabilities. Moreover, data discrepancies and lack of synchronization between the dual technologies severely affect the accuracy of cost control. Additionally, insufficient integration depth between the dual technologies impacts their ability to compare budgets with actual cost expenditures in real-time, leading to budget identification lag risks and potential project financial losses [9].

## 4. Innovative optimization paths for BIM and AI integration on construction sites

### 4.1. Constructing a dynamic progress control innovation path for dual-technology integration

BIM and AI integration control technologies face issues of lagging control in construction site progress management, unable to effectively predict progress risks and potentially exposing construction enterprises to risks of default and overspending. To address these issues, a dynamic progress control model can be constructed based on the dual-technology integration mechanism. Firstly, utilize BIM models and AI dynamic data processing technologies to construct a dynamic progress monitoring model, embedding BIM's process logic model and AI's information collection model to simulate the construction process through their collaboration. During model operation, AI provides timely and accurate data to the BIM model, enabling dynamic corrections and ensuring the model stays synchronized with actual construction conditions. Secondly, leverage BIM and AI collaboration to form an integrated progress control and detection system. BIM technology accurately and in real time annotates construction progress nodes to ensure visual and appropriate progress control. Meanwhile, AI technology generates real-scene comparisons of visual progress through real-scene rendering, facilitating multi-dimensional progress monitoring by control personnel. Additionally, this joint technology not only ensures progress control efficiency but also supports construction management traceability. Finally, establish a progress control review mechanism through dual-technology integration. After completing each construction node, deeply analyze and accurately calculate the progress control models and data using BIM and AI technologies to identify loopholes in progress control and provide detailed and effective references for subsequent progress control work.

### 4.2. Establishing a refined quality control optimization path for dual-technology integration

Quality control on construction sites is crucial, and the integration of BIM and AI technologies can construct a comprehensive monitoring model to accurately identify and analyze quality issues during construction and propose rectification suggestions. Firstly, utilize BIM + AI technology to simulate project processes and workflows during the pre-construction phase to achieve quality risk control. BIM technology primarily constructs engineering model simulations for civil engineering, electromechanical, and other processes in building construction, while AI technology embeds quality control thresholds, industry standards, and other parameters for each project node in the model, forming a quality supervision linkage. Once quality issues arise in the project, the model automatically issues alarm prompts, enabling proactive quality control. Secondly, utilize BIM+AI integration technology to construct a quality prevention and control mechanism during the construction phase. AI technology is responsible for quality appearance identification, while BIM handles coding control. Their collaboration quickly locates the position and component model of quality issues, establishing an integrated quality control mechanism for identification, location, rectification, re-inspection, and cancellation [10].

### 4.3. Improving a proactive safety control enhancement path for dual-technology integration

Intelligent management of construction site safety control emphasizes the principle of "proactive prediction and active management." Therefore, in the development of BIM + AI integration, a comprehensive management mechanism needs to be constructed based on construction site control requirements, utilizing AI technology to accurately identify and integrate risks during construction and compile them into a risk list for subsequent supervision. For instance, AI technology can be used to sort out and identify the risk list, analyze various risk inductions, and mark key prevention and control areas on the BIM model. During construction, management personnel should proactively implement risk prevention and control work according to the model markings. Additionally, construct a BIM + AI construction safety closed-loop control mechanism. This mechanism applies AI visual identification and data capture technologies as its core, timely extracting information on on-site violation operations (non-compliant operations), machinery operation status, etc., and constructing a construction condition safety control database. BIM technology can then verify the model based on the data information formed by AI, further refining construction safety hazards and providing a more robust safety barrier for subsequent risk level classification and prevention and control.

### 4.4. Creating a full-lifecycle cost control upgrade path for dual-technology integration

Under the integration of BIM and AI technologies, cost control on construction sites needs to optimize control paths from three dimensions: budgeting, cost control, and accounting. Firstly, during the construction budgeting phase, utilize the BIM + AI model to improve the efficiency of engineering quantity accounting. The BIM model comprehensively displays the usage of construction materials, project duration, and construction techniques, avoiding omissions or duplicate accounting and ensuring accounting accuracy. AI technology can continuously revise budget amounts through collaboration with the BIM model and comprehensive extraction and calculation of data information such as market material prices and material usage, avoiding budget deviations. Secondly, during construction, utilize the dual-technology integration system to establish a cost deviation prevention and control mechanism. BIM technology is used to integrate and classify various cost data during construction, keeping pace with construction progress and synchronously updating changes in various construction cost data. AI, on the other hand, uses the data from the BIM model to accurately calculate and compare cost variations, reasonably allocating construction resources based on the causes of deviations to achieve dynamic and accurate cost control objectives. Finally, construct a BIM + AI joint review model during the completion phase. This model summarizes cost and pricing data throughout the construction cycle and links cost control with other management work. BIM technology is responsible for simulating and replicating the construction process, while AI technology identifies and attributes weak points in cost control throughout the entire process and automatically generates cost control rectification reports to avoid the recurrence of cost control risks.

## 5. Conclusion

In summary, under the intelligent management model of construction sites, the integration path of BIM and AI is key to enhancing the precision and scientificity of construction site management. The application of BIM models and AI algorithms can construct dynamic engineering models, providing managers with visual mechanisms for construction progress, quality, safety, and cost control. This enables managers to effectively prevent construction site control risks through the construction of targeted management mechanisms. In the future, intelligent management of construction sites can combine the advantages of BIM and AI technologies to form a deeply integrated control mechanism, promoting the high-quality transformation of construction site management work.

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## Disclosure statement

The authors declare no conflict of interest.

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