

Application of Smart Management Technology in Municipal Engineering

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Abstract: With the development of smart cities, the scale and quantity of municipal construction projects continue to increase, while construction techniques and technologies are constantly innovating. This has led to the gradual emergence of issues in traditional extensive municipal engineering management practices. The application of smart management technology enables comprehensive technological means to manage municipal engineering projects throughout their entire lifecycle, implementing precise control measures for each construction phase, thereby enhancing engineering management efficiency and quality. This article will analyze the connotation of smart management technology and explore its specific application methods in conjunction with various stages of municipal engineering. Finally, based on the current application status of smart technologies, corresponding suggestions will be proposed to promote the intelligent transformation of municipal engineering management.

Keywords: Smart management technology; Municipal engineering; BIM technology; Digital twin model

Online publication: Jun 11, 2026

1. Introduction

The development of urbanization has placed higher demands on the control of construction quality and progress in municipal engineering projects, and traditional experience-based management methods can no longer meet the current needs of municipal engineering management^[1]. Therefore, in recent years, China's municipal construction management has gradually transitioned towards intelligent management. The application of intelligent management technologies in municipal engineering management promotes the digital transformation of traditional experience-based control models, enabling linked control across various project processes. This fundamentally addresses the drawbacks of traditional single-point control and lays the foundation for the efficient development of municipal engineering projects.

2. The connotation of intelligent management technologies

Intelligent management technologies refer to collaborative management technology models constructed using

artificial intelligence, big data, Internet of Things (IoT), and other technological means, with data collection, analysis, modeling, and application as key supports ^[2]. The characteristics of intelligent management technologies lie in their integration of multiple technological models, enabling precise identification of deficiencies in municipal engineering control through accurate data analysis, and the formulation of corresponding control plans to achieve precise and full-process control of projects. Intelligent management technologies can be divided into four management modules in municipal engineering management: First, technology-driven data management. In project management, technologies such as sensors and drones can be used to collect relevant data from the project site, providing data support for the establishment of subsequent management models and effectively eliminating the subjective management drawbacks of traditional empiricism. Second, collaborative and linked management. Intelligent management technologies can effectively address information asymmetry issues across various management stages and departments by providing a basis for collaborative operations through information aggregation. Third, intelligent predictive capabilities. The application of intelligent management technologies enables the early identification of control risks through the construction of construction models before project management issues arise, ensuring efficient risk control ^[3].

3. The application of intelligent management technologies in various stages of municipal engineering projects

3.1. Application of intelligent management technologies in the design stage of municipal engineering projects

The design stage of municipal engineering projects is the overall planning phase, encompassing tasks such as on-site data aggregation, drawing preparation, and construction plan formulation ^[4]. However, traditional construction design primarily employs two-dimensional design and textual descriptions, making it difficult to form intuitive design content and lacking sufficient participation from various departments, hindering the realization of collaborative effects. The application of intelligent management technologies can leverage engineering data to construct three-dimensional models (GIS geographic information systems and BIM technology), thereby visually presenting information such as construction site topography, engineering structures, and pipeline routes to relevant departments. Furthermore, the three-dimensional design approach not only facilitates the timely identification of design issues by designers but also enhances the accuracy of construction cost estimation, effectively preventing design changes and budget overruns during construction. Additionally, the application of intelligent technologies in design provides a collaborative communication platform (artificial intelligence collaborative design platform) for project participating departments, enabling the sharing of design data and providing designers with design opinions from different disciplines to ensure the completeness of the design. The types and parameters of technologies applied in intelligent management during the design stage can be found in **Table 1**.

Table 1. Application parameters of intelligent management technologies

Smart management technical parameter	Parameter	Technical mode	Application function
GIS spatial positioning accuracy	± 0.5 m	GIS (Geographic Information System)	Construction terrain and on-site survey

Engineering quantity calculation error	$\leq 3\%$	BIM Technology	3D model construction and cost accounting
Collaborative design speed	$\leq 3s$	AI Collaborative Design Platform	Multi-department collaborative design

3.2. Application of intelligent management technologies in the construction stage of municipal engineering projects

The construction stage of municipal engineering projects is the implementation phase of the main building structure, involving a wide range of engineering management tasks. Management personnel need to strengthen control from multiple dimensions, including construction progress, quality, and safety. Meanwhile, the complex environment and large number of personnel on municipal construction sites lead to an increase in uncontrollable factors. In such cases, relying solely on manual inspections and paper-based information exchange can significantly impact construction management efficiency^[5]. Moreover, delayed or inadequate information transmission can easily result in misalignment in engineering management tasks, potentially leading to quality and safety risks in severe situations. The application of intelligent management technologies enables comprehensive control over construction projects, fosters collaboration among departments, and enhances construction management and communication efficiency. Firstly, in terms of construction progress control, BIM technology can be utilized to construct a construction progress model based on the construction plan and conditions. Simultaneously, sensors can be employed to collect real-time construction data on-site for simulating the actual construction progress. By comparing these two models, the reasonableness of the construction progress can be assessed. If significant deviations in the construction progress are detected, the system automatically issues an alert, prompting progress management personnel to promptly identify the cause and adjust the construction plan to resolve project delays. Secondly, for construction quality control, the Internet of Things (IoT) can be employed to monitor the construction process in real-time. Sensors for various construction parameters, such as temperature and compaction, can be deployed on-site to continuously monitor construction quality and upload the monitoring data. This allows management personnel to assess construction quality and mitigate quality risks. Thirdly, in construction safety control, AI video recognition technology can be adopted to identify safety risks during construction, providing references for safety management. For instance, in deep foundation pit construction, identification devices for parameters such as foundation pit displacement and subsidence can be deployed to issue early warnings about safety issues. Once the monitored parameters exceed the threshold, the system automatically triggers an alarm, prompting construction personnel to promptly reinforce the foundation pit and evacuate to prevent personnel casualties caused by foundation pit collapse^[6]. Furthermore, AI video recognition technology can accurately identify whether construction personnel are wearing safety protective gear and detect any non-compliant operations. Upon detecting non-compliant behavior, the system automatically issues voice alerts and pushes the non-compliance information to the management personnel's terminals, providing references for safety management rectification work. Finally, in construction resource management, the application of intelligent management technologies enables the identification and analysis of information such as construction progress and material usage patterns to determine the application time of inventory materials. This facilitates reasonable planning for material procurement, arrival, and usage, avoiding excessive material accumulation on-site that leads to management cost waste or delayed material transportation that affects project progress. To ensure a more concise and clear discussion of the application

of intelligent management technologies in the construction stage of municipal engineering projects, **Figure 1** is used to analyze the specific application process.

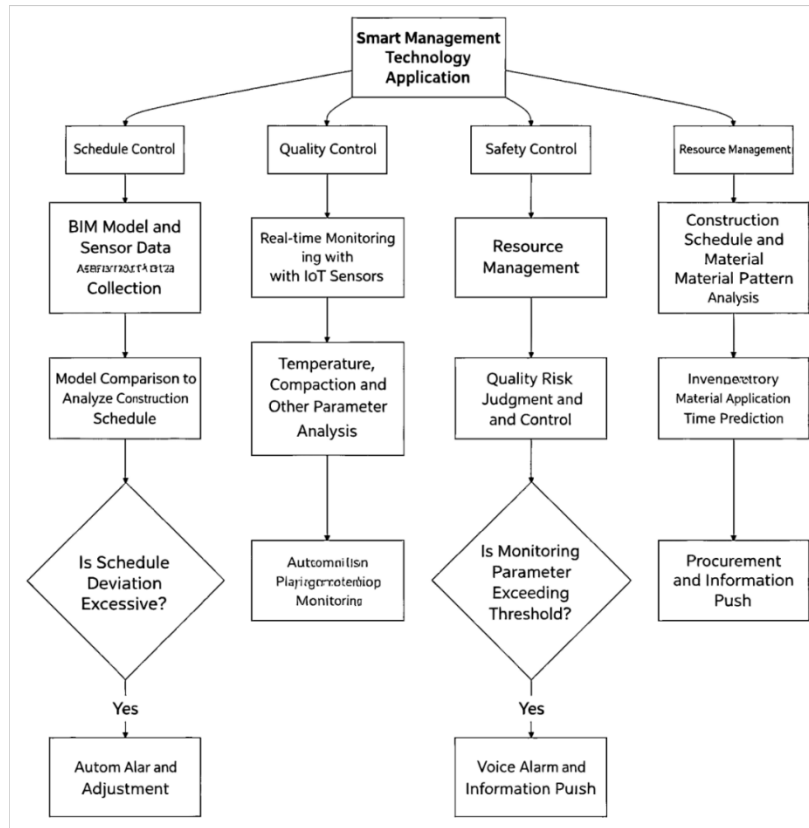


Figure 1. Application of smart management technology in the construction phase of municipal engineering projects.

3.3. Application of smart management technology in the acceptance phase of municipal engineering projects

Project acceptance during municipal engineering construction is pivotal for quality control. The primary tasks in this phase involve comparing the construction results with design standards and industry norms to determine whether the project meets delivery criteria. Traditional municipal engineering projects mainly rely on manual acceptance methods, which are not only inefficient but also prone to human measurement errors, leading to inaccurate acceptance results and affecting the project delivery process. The application of smart management technology in the acceptance phase can transform the traditional on-site measurement acceptance method into a virtual model acceptance mode. Acceptance personnel can construct a BIM engineering model through data collection and compare it with the design model to quickly identify differences and promptly investigate the causes of deviations. Moreover, the model can reflect various parameters of the construction project in real-time, offering more precise and comprehensive data compared to manual measurements, effectively avoiding operational errors and omissions in manual acceptance. Taking the acceptance of pipeline network projects as an example, BIM model comparisons can quickly inspect information such as the buried depth and direction of the pipeline network to determine if it meets design requirements [7]. Simultaneously, simulating construction parameter models enables precise detection of parameters such as the slope and flatness of the pipeline network, with the detected data automatically stored

in the project archives for future quality issue tracing. Compared to manual acceptance, the application of smart management technology in the acceptance phase offers significant advantages in terms of the accuracy of parameter measurements and inspection efficiency, effectively avoiding the influence of external factors and human experience on acceptance results. Furthermore, it enables non-destructive testing of the project, such as using radar or laser technology to inspect the internal structure of concrete, ensuring the accuracy of inspection results. Additionally, the application of digital platforms in project acceptance facilitates the construction of a collaborative acceptance platform. This allows construction personnel, supervisors, designers, and others to participate jointly in the acceptance process and provide acceptance opinions from different professional perspectives, facilitating the timely identification and resolution of project issues. Moreover, acceptance reviews by various departments can also be completed through digital platforms, reducing the delivery time of review materials and thereby shortening the acceptance cycle.

3.4. Application of smart management technology in the operation and maintenance phase of municipal engineering projects

The task of operation and maintenance management involves the operation and maintenance of infrastructure after the delivery of municipal engineering projects. This phase has a long duration and needs to run through the entire process of project operation. The management goal in this phase is to identify and address potential quality hazards and defects in the project to ensure its operational quality. Traditional municipal engineering operation and maintenance primarily rely on manual inspections and post-incident remediation, which is a passive approach. If defects are not identified promptly, the scope of the defects may continue to expand, affecting subsequent repair quality and increasing maintenance costs. The application of smart management technology in the operation and maintenance management phase can transform the operation and maintenance management mindset from passive response to proactive prevention and control, enabling regular project inspections^[8]. Firstly, a combination of monitoring technology and IoT technology can be used to monitor faults and defects in municipal engineering projects. For example, water level sensors can be installed in pipeline network projects, and settlement sensors can be installed at roadbed locations to collect operational parameters of the project in real-time for operation and maintenance personnel to assess the project's operational status. Simultaneously, operation and maintenance personnel can set risk thresholds in the intelligent detection system. Once parameters reach the threshold range, the system will automatically issue warnings, prompting operation and maintenance personnel to take timely and effective corrective measures and conduct fault investigation and prevention. For instance, in the operation and maintenance management of road and bridge projects, drones can be used for regular inspections of bridges, with inspection data automatically uploaded to ensure the accuracy and timeliness of data collection. Secondly, integrating big data and artificial intelligence technologies can enhance project risk prediction capabilities. Big data technology can collect and analyze various parameters during project operation, such as project defects and maintenance records. Artificial intelligence technology can then be used to predict project risks and develop operation and maintenance management plans based on the prediction results for proactive prevention and control, thereby improving fault prevention and control efficiency and reducing operation and maintenance costs. For example, in the operation and maintenance management of drainage pipeline networks, data analysis of pipeline operation may reveal a slowdown in water flow velocity and a reduction in water volume, indicating a potential blockage in the pipeline. Simultaneously, artificial

intelligence can analyze the water flow velocity to determine the scope of the blockage, allowing operation and maintenance personnel to promptly clear the blockage in advance and avoid risks such as pipeline bursts caused by blockages. Additionally, the application of big data technology facilitates the rational optimization of operation and maintenance resource allocation. It can reasonably allocate inspection and operation and maintenance personnel based on the project's operational status and fault occurrence patterns, ensuring optimal resource allocation. Finally, the integrated application of BIM and GIS technologies in the operation and maintenance of municipal facilities can accurately locate project faults, reducing the time required for fault investigation during operation and maintenance ^[9].

4. Recommendations for the application of smart technologies in municipal engineering projects

The application of smart management technology in municipal engineering project management can enhance the quality and efficiency of full-process project control. However, certain issues still exist in practical applications, necessitating further optimization and improvement of smart management technology:

Firstly, ensure the adaptability of technology to management tasks. Different types of municipal engineering projects and construction phases have varying management needs. Therefore, reasonable technology solutions should be selected based on project requirements when applying smart technologies to avoid template-based applications. Simultaneously, attention should be paid to the integrated application of technologies to achieve complementary advantages and provide more powerful technical support for municipal management by constructing a joint intelligent technology platform.

Secondly, strengthen the optimization of the data system. The application of smart management technology relies on data as its core carrier. If the data system is improperly constructed, leading to inaccurate data, it will inevitably affect the efficiency of smart management technology applications. Based on this, municipal management departments need to optimize the data system and construct an integrated database for data collection, storage, analysis, and application to ensure data integrity. Additionally, standardize the data in the database to avoid affecting compatibility during data transmission and provide favorable conditions for data sharing among departments.

Thirdly, improve smart management systems. Management systems serve as the basis for implementing management tasks. When formulating systems, construction industry standards should be used as references, and targeted management norms should be developed based on the characteristics of municipal engineering projects. Simultaneously, strengthen the security control of smart management technology applications to ensure the security of data during collection, transmission, and application. Finally, improve smart evaluation mechanisms to assess the application effects of smart management technology and promote continuous optimization of its application ^[10].

5. Conclusion

In summary, the application of smart management technology in municipal engineering project management can effectively overcome the drawbacks of traditional manual management, enable visual management and facilitate the timely identification of construction issues by management personnel to avoid project construction changes or rework. Simultaneously, it can conduct real-time supervision of the quality, safety,

and progress of the construction process, improving project control efficiency. Moreover, the application of smart management technology in post-construction operation and maintenance can transform passive approaches into proactive ones, achieving precise prevention and control of project faults. In the future, as smart management technology continues to evolve, its application scope in municipal engineering projects will become broader. However, it is still necessary to ensure the adaptability of technology to management content and implement effective data security control to provide long-term guarantees for the in-depth integration of smart management technology and municipal management work.

Disclosure statement

The authors declare no conflict of interest.

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