

# Technological Innovation and Project Benefit Improvement in Construction Management

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**Abstract:** In the context of the “dual carbon” goals and digital transformation, technological innovation has become the core driving force for enhancing the management efficiency and overall benefits of building projects. Digital tools (BIM, IoT, AI) are reshaping design and construction collaboration mechanisms, while intelligent equipment (drones, robots) is optimizing work efficiency and safety. Green technologies (low-carbon materials, waste regeneration) are promoting sustainable development. Dynamic management models drive resource allocation and risk warnings through real-time data, achieving precise control over costs, quality, and schedules, with project comprehensive benefits improving by 20–30%. Issues such as insufficient technology integration and high application barriers for small and medium-sized enterprises urgently need to be addressed. Accelerating the industry’s transition towards high-efficiency and low-carbon directions requires policy support, the construction of a technological ecosystem, and the cultivation of versatile talent.

**Keywords:** Technological innovation; Engineering benefit; Intelligent construction

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## 1. Introduction

At a critical juncture for transformation and upgrading, China’s construction industry faces accelerated technological innovation driven by climate change and resource constraints. Aligned with the “dual carbon” objectives and modern industrial system requirements, the sector must shift toward green and intelligent practices to achieve lifecycle carbon reduction and efficient resource utilization. Research indicates that technologies like AI and BIM can optimize construction management, cutting project costs by 10% to 20%, while green materials and prefabrication techniques may reduce carbon emissions by 30%, delivering both environmental and economic benefits. Through literature analysis, case studies (e.g., NickyAI’s intelligent management platform, TRIQBRIQ’s modular systems), and technical validation, this study explores how technological innovation drives engineering efficiency and profitability. It offers theoretical support for policymaking and corporate practices, supporting the industry’s sustainable growth through existing stock renovation and innovative expansion.

## **2. Drivers of construction technology innovation**

### **2.1. Real-world needs of industry development**

The construction industry is under the rigid constraints of green transformation and sustainable development goals. This makes it a must-have to push for technological innovation. The introduction of the global “dual-carbon” goals requires a reduction in carbon emissions throughout the entire life cycle of buildings. The green building evaluation system has forced the research and development and application of energy-saving materials, low-carbon processes, and renewable energy technologies. At the same time, the increasingly prominent contradiction between rising labor costs and the shortage of natural resources has made the traditional extensive construction model unsustainable. The introduction of mechanization and automation technologies has become the key to reducing labor dependence and improving resource utilization efficiency. With the development of housing construction towards high-rise, prefabricated, and intelligent directions, the structural complexity has significantly increased. The precision of construction and the difficulty of collaborative management have been upgraded. There is an urgent need to rely on digital tools such as BIM (Building Information Modeling) and the Internet of Things to achieve integrated design and construction and refined management throughout the entire process. The diversified evolution of industry needs together constitutes the underlying driving force for technological innovation <sup>[1,2]</sup>.

### **2.2. Driving forces of technological advancement**

The rapid adoption of digital technologies has become the cornerstone of innovation in the construction industry. BIM (Building Information Modeling) revolutionizes design-construction collaboration through 3D modeling and data integration, while IoT enables real-time monitoring and intelligent control of equipment, materials, and worksite conditions. AI algorithms further optimize decision-making in areas like schedule forecasting and risk prediction, significantly boosting management efficiency and precision <sup>[3]</sup>.

The maturation and widespread use of intelligent equipment are accelerating industry transformation: construction robots replace high-risk, repetitive tasks; drones minimize manual intervention via high-precision surveying and progress tracking; and automated machinery like smart cranes and driverless transport vehicles break through traditional productivity barriers.

Simultaneously, breakthroughs in materials and techniques continue to push boundaries: carbon-reduced concrete cuts lifecycle emissions, and 3D printing enables rapid fabrication of complex structures—propelling construction toward greater efficiency and sustainability. This systemic technological evolution creates multi-dimensional synergies, forming the core engine of industry advancement.

## **3. Practical applications of technological innovation in housing construction**

### **3.1. Digital tools empowering construction management**

The deep integration of digital tools has reshaped management practices in housing construction. BIM technology optimizes design solutions through 3D modeling and lifecycle data integration, enabling multidisciplinary clash detection during design phases. Construction simulations preemptively identify risks, reducing rework rates.

IoT networks deploy sensors to collect real-time jobsite data—temperature, humidity, noise, and equipment status—while edge computing facilitates automated environmental alerts and machinery adjustments, accelerating response efficiency <sup>[4]</sup>.

Big data analytics synthesizes historical project records with real-time information flows to build predictive scheduling models and dynamic resource allocation systems. This precision-matches labor, materials, and equipment needs, minimizing delays and cost overruns.

Together, these technologies form a design-monitor-decide closed-loop system, driving construction

management toward data-driven intelligence and collaborative evolution.

### **3.2. Smart construction equipment boosts efficiency**

The large-scale adoption of smart construction equipment has significantly improved both efficiency and safety in building projects. Construction robots, programmed to handle high-risk or repetitive tasks like bricklaying and welding, achieve millimeter-level precision, reducing human error and shortening work hours <sup>[5]</sup>. For instance, welding robots can operate continuously with weld qualification rates exceeding 98%. Drones equipped with multispectral sensors and LiDAR rapidly survey large areas, generating high-precision 3D point cloud models. They simultaneously monitor real-time progress through aerial imaging, boosting efficiency by over 5 times compared to manual inspections. Automated machinery overcomes traditional equipment limits: AI-powered smart cranes optimize lifting paths to reduce idle rates and collision risks, while unmanned transport vehicles use SLAM technology for round-the-clock precise material delivery, cutting labor dependency and accident rates. The collaborative use of these smart technologies is driving construction processes toward standardization and unmanned operations.

### **3.3. Green technologies drive sustainable development**

Green technologies are reducing carbon emissions throughout the entire building lifecycle. Solar-integrated glass generates power on-site, cutting external energy dependence, while phase-change materials regulate indoor temperatures through latent heat absorption, boosting passive energy efficiency. Construction waste recycling technology converts discarded concrete and steel into recycled aggregates or components, achieving over 70% resource recovery rates – slashing raw material consumption and landfill pollution. In low-carbon construction practices, dry construction methods minimize dust and wastewater, and modular building techniques reduce material waste and carbon emissions by 30% through prefabricated assembly. The systematic adoption of these technologies is driving the industry toward a sustainable model characterized by circular resource use, low carbon footprint, and high efficiency.

## **4. The restructuring of engineering management models by technological innovation**

### **4.1. Intelligent transformation of management models**

#### **4.1.1. Collaborative platform development**

Cloud computing breaks down data silos in traditional project management, enabling cross-departmental collaborative platforms. Through cloud-based data storage and computing, all stakeholders – including designers, contractors, and supervisors – can share real-time access to BIM models, progress reports, and resource inventories, ensuring information consistency. These platforms integrate ERP (Enterprise Resource Planning) and PM (Project Management) systems to automatically synchronize design modifications with construction schedules while dynamically generating resource allocation plans, reducing manual coordination costs <sup>[6]</sup>. Supported by data visualization tools, collaborative decision-making allows multi-role online reviews and conflict resolution. For instance, cloud-based BIM clash detection slashes issue response time by over 60%, significantly enhancing management efficiency.

#### **4.1.2. Dynamic risk monitoring systems**

AI algorithms are shifting engineering safety management from reactive to proactive prevention. Computer vision systems analyze live site footage to identify hazards like missing safety gear or unsafe operations with over 90% accuracy <sup>[7]</sup>. Sensor networks combined with deep learning track parameters such as foundation deformation

and scaffold loads, predicting risks and triggering tiered alerts. Trained on historical data, the system generates response protocol libraries that automatically match optimal solutions – for example, mapping evacuation routes and activating firefighting equipment during fires. This technology compresses risk response time to under 15 minutes while reducing major accidents by 40%, creating an intelligent, closed-loop safety management process.

## **4.2. Standardization and optimization of management processes**

### **4.2.1. Standardized restructuring of construction workflows**

BIM technology enables 3D visual decomposition of construction sequences, specifying critical parameters and inspection criteria to create standardized work documents (e.g., 4D simulations optimizing concrete pouring). AR tools replace traditional blueprints by visually displaying complex structural details, reducing construction errors and rework. These standardized processes integrate with schedule management modules to monitor deviations in real time: Delays in critical phases like steel reinforcement binding automatically trigger alerts and generate adjustment plans. This establishes a dynamic closed-loop control system, enhancing workflow coordination and quality stability.

### **4.2.2. Data-driven resource allocation**

IoT and big data technologies are shifting resource allocation from experience-based decisions to data-driven approaches. Real-time data on workforce attendance, material inventory, and equipment status—captured via RFID tags and sensors—creates a digital twin model of resource conditions<sup>[8]</sup>. Scheduling systems combine genetic algorithms and machine learning to forecast future needs, dynamically generating optimal allocation plans. For instance, concrete delivery schedules adjust batching plant dispatch frequency in real-time based on weather data and pouring progress. Equipment-sharing platforms integrate regional project demands to intelligently redeploy idle machinery across sites, boosting utilization rates by over 20%. This smart scheduling moves beyond traditional “fixed-plan” distribution, enabling flexible allocation of labor, materials, and equipment. As a result, resource idle rates drop by 15–30%, significantly lowering overall costs.

## **5. Pathways for technological innovation to enhance project efficiency**

### **5.1. Cost control and resource optimization**

#### **5.1.1. Dynamic cost management**

Integrated BIM and ERP systems enable real-time cost control: BIM incorporates quantity takeoffs and market prices to instantly track cost impacts of design changes, while ERP syncs supply chain data to build a lifecycle cost database. Dynamic accounting modules automatically compare budgets against actual expenditures—triggering alerts and tracing sources when concrete usage deviations exceed 5%, with cost report generation accelerated to hourly updates. Multi-dimensional forecasting models simulate economic impacts of alternatives (e.g., optimizing formwork reuse to reduce amortized costs), enabling faster decisions. This approach cuts cost accounting errors by 25% and improves capital turnover efficiency by 15–20%.

#### **5.1.2. Resource recycling strategies**

Standardized prefabricated components and modular temporary facilities significantly boost resource efficiency: Factory-made elements reduce material waste by 60–70% compared to cast-in-place construction, while their detachable design allows reuse across multiple projects for over 5 cycles. Temporary structures use modular components like prefabricated enclosures and telescopic scaffolding, managed via QR codes for rapid assembly/disassembly and cross-site redeployment—achieving 80% reuse rates. Recycled construction waste aggregates



replace natural gravel in temporary roads, cutting material costs by 30%. These circular approaches reduce project-specific carbon intensity by 15–25%, enhancing both project efficiency and environmental sustainability.

## **5.2. Enhanced quality and safety management**

### **5.2.1. Digital quality control systems**

Laser scanning and AI image recognition are revolutionizing traditional quality inspection. 3D laser scanners mounted on robotic platforms perform daily site-wide sweeps, creating high-fidelity point cloud models that automatically compare structural dimensions against BIM designs with millimeter-level precision, identifying deviations down to 2mm<sup>[9]</sup>. For instance, automated alerts trigger on-site tablets and management dashboards when wall verticality exceeds 3mm tolerance, enabling immediate correction while boosting inspection efficiency by 80% over manual methods. AI algorithms deployed on edge computing devices analyze concrete surface appearance in varying light conditions to detect micro-cracks (< 0.1mm), honeycombing, and other defects in real-time with over 95% accuracy, completely replacing subjective visual checks. All quality data streams instantly upload to a cloud-based knowledge repository, where machine learning correlates findings with responsible teams and historical rectification records. This forms a self-improving, traceable quality control loop – automatically generating preventive maintenance suggestions while slashing inspection cycles by 40% and reducing rework rates by 15–20% across project phases. Field engineers now focus on value-added analysis rather than manual measurement, fundamentally transforming quality assurance workflows.

### **5.2.2. Intelligent safety alert systems**

Wearable devices and AI systems create proactive safety networks; Smart helmets embedded with biometric sensors track workers' locations via UWB positioning and monitor vital signs like heart rate and core body temperature. These automatically issue personalized rest alerts through vibration and audio prompts in high-temperature environments—simultaneously activating site ventilation systems—reducing heatstroke incidents by 60%. AI surveillance powered by computer vision identifies unsafe behaviors across 360° camera networks, such as missing safety harnesses or unauthorized entry into geofenced danger zones, with over 90% accuracy. When risks are detected, linked alert systems instantly broadcast warnings on-site displays and supervisors' tablets while temporarily disabling nearby machinery. Deep learning models continuously analyze historical incident data and real-time environmental factors (e.g., wind speed, structural loads) to predict emerging risks like falls or scaffold collapses, triggering automated work stoppages and allowing proactive schedule adjustments before hazards materialize. Since implementation, near-miss reporting has increased by 40% due to heightened risk awareness, minor site injuries have dropped by 35%, and emergency response times shortened to under 5 minutes through optimized evacuation routing. This integrated approach fundamentally shifts safety management from reactive fixes to predictive prevention—transforming compliance into a culture of collective vigilance where workers actively participate in hazard reporting via mobile interfaces.

## **5.3. Schedule compression and efficiency breakthroughs**

### **5.3.1. Intelligent scheduling technology**

Genetic Algorithm (GA) models overcome traditional scheduling limitations by simulating biological evolution through crossover, mutation, and selection operations. Running on cloud-based optimization engines capable of processing millions of constraint combinations per minute, these models iteratively refine solutions over thousands of generations. This computationally intensive process optimizes task sequencing, resource allocation, and critical path analysis while resolving complex multi-trade workflow conflicts—particularly valuable for projects with interdependent mechanical, electrical, and structural activities. Integrating historical performance benchmarks

with live IoT feeds from equipment and weather stations, the system dynamically generates globally optimal plans validated through Monte Carlo simulations. For instance, streamlining steel reinforcement sequencing and formwork staging in a 50-story high-rise project reduced critical path duration by 12%, saving 36 calendar days. Crucially, the system enables dynamic adjustments during execution. When material deliveries lag via GPS tracking or sudden thunderstorms disrupt outdoor work, its adaptive engine automatically restructures task logic using fuzzy logic-based scenario planning—recalculating dependencies within minutes and boosting schedule modification efficiency by 70%. Project managers validate changes through intuitive drag-and-drop Gantt interfaces before deployment. This achieves millimeter-precise schedule control while maximizing resource utilization, typically reducing equipment idle time by 25% and enabling proactive subcontractor coordination through automated notification workflows.

### 5.3.2. Parallel construction & real-time adjustment

The integrated use of drones and BIM technology establishes a real-time monitoring loop for progress control <sup>[10]</sup>. Daily high-frequency drone flights generate point cloud models of construction sites, which automatically compare against BIM planning models to identify schedule deviations and quantify delays. Using SLAM algorithms, the system pinpoints bottlenecks in real-time – for example, heat mapping revealed lifting efficiency issues in a prefab project, prompting immediate reprioritization of module deliveries. Adjustment instructions push directly to field teams via mobile devices, dynamically reallocating machinery and labor to reduce delays by 25%. Parallel workflows are further optimized, such as simultaneous underground work and above-ground prefabrication. Real-time monitoring prevents clashes between operations, boosting overall efficiency by 18-30% and increasing schedule compliance to over 95%.

## 6. Conclusion

Technological innovation, spanning digitalization, intelligence, and sustainability, is driving construction industry transformation. BIM, IoT, and AI have reshaped design-construction collaboration, while smart equipment and green processes boosted schedule compliance and resource utilization by 20–30%. However, challenges persist. Cross-system integration gaps create data silos, and SMEs' smart equipment adoption rates remain below 15%. Future priorities include: deepening BIM-ERP integration to build open technology ecosystems; implementing supportive policies like tax incentives and standards to lower SME adoption barriers; fostering industry-academia collaboration to develop multidisciplinary talent and refine smart construction certification systems. These steps will accelerate industry-wide benefits, steering construction toward an efficient, low-carbon, and sustainable future.

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