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# Factors Affecting Quality Control and Optimization during Building Construction

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**Abstract.** Quality control during the construction phase of building engineering is a core element determining project safety. This paper systematically analyses the multidimensional factors affecting construction quality, focusing on the impacts and problems caused by human factors, time factors, geological and climatic factors, and engineering materials and equipment. Based on these problems, targeted optimization suggestions are proposed, including establishing a systematic and hierarchical governance system to strengthen personnel management, constructing a collaborative management system for schedule and quality to address time risks, establishing a survey-monitoring-prevention system to address environmental and climatic impacts, and building a digital traceability and intelligent operation and maintenance system to address risks related to engineering materials and equipment. This paper aims to provide references and practical paths for improving construction quality, contributing to the high-quality, sustainable development of the construction industry. This study focuses on the core issues of construction quality, and the systematic countermeasures proposed have a strong practical guiding significance, which can effectively enhance engineering quality.

**Keywords:** Building Construction; Factors Affecting Construction Quality; Quality Control; Optimization.

## 1. Introduction

In the first half of 2025, the total output value of China's construction industry reached 13.67 trillion yuan, a year-on-year decrease of 1.13%. Labor productivity, at 323,000 yuan per person, increased to 9.81% year-on-year, indicating that the construction industry is shifting towards a technology-intensive model[1]. Among all construction projects, the proportion of urban renewal projects increased, the total construction area of housing projects decreased, and the completed area of residential projects remained the largest. Improving the quality and efficiency of the construction industry promotes high-quality economic development, and the quality of construction projects not only affects people's lives and property but also social harmony and stability [1]. With the promotion of new models such as prefabricated buildings and intelligent construction, the risks to quality during construction are increasing, and the original quality management system is facing new challenges.

The quality of building has a vital role in the safety of the population, the well-being, and the nation. Whether it is large infrastructure such as bridges and tunnels or residential and civic structures like schools and hospitals, their quality level serves as the foundation for the stable operation of the economy and society. Quality control during the construction phase is influenced by various factors, including personnel, materials, equipment, technology, and the environment, such as roof flashing height, expansion joint spacing, and concrete strength. Even minor deviations can lead to significant quality problems during construction. Therefore, in-depth research into the factors affecting construction quality not only helps improve the quality of building projects but also provides a reference for promoting technological upgrades in the industry and improving the overall quality of the construction sector.

[1] https://mp.weixin.qq.com/s/zNZqUVvfSCJ15KxVZNLISQ

Scholars have already researched the quality of building construction projects. Bian Haihong explored precise quality control methods for the processing of steel structure components [2]. Cao Yifan analyzed measures to control costs during the bidding process effectively [3]. Pan Qianyu studied the influencing factors and countermeasures of the construction project cost budget [4]; Ibironke O , Ibironke D. studied the factors affecting time, cost, and quality management in building construction projects [5]; M. Abas et al. and others discussed the assessment of factors affecting the quality of construction projects [6]; Rawaa Hijazi studied the factors affecting the quality performance of construction projects [7]. This paper primarily examines the factors affecting construction quality, including human factors, time factors, geological and climatic factors, and engineering materials and equipment.

The contributions of this paper are mainly in two aspects. First, it studies the factors affecting construction quality across four dimensions — human factors, time, environment and climate, and materials and equipment — and analyzes the impact of each on quality. On the other hand, based on an analysis of the factors affecting quality during the construction phase, this paper proposes innovative and feasible optimization strategies for each influencing factor, aiming to provide a reference for research on construction quality and the development of building engineering.

## 2. Main Factors Affecting the Construction Quality Control

### 2.1. Human Factors

#### 2.1.1. Management: The dual shortcomings of professional competence and sense of responsibility

The management team includes project managers, technical leaders, and quality supervisors. The top-level design and key decisions made by the management team are crucial to project quality. If project managers deviate from a balanced approach to quality, schedule, and cost, they may sacrifice quality under time pressure. If quality supervisors lack a deep understanding and firm grasp of current standards, they will struggle to implement practical judgment and precise control in complex construction environments. Liu Pingan points out that although enterprises have established quality management frameworks, issues at the execution level, such as professional competence, sense of responsibility, qualification levels, and technical proficiency, prevent timely response and closed-loop handling of quality problems, reflecting the reality of inadequate implementation of management responsibilities and a lack of professional capabilities [8].

#### 2.1.2. Operational level: Lack of skills and widespread weakness in quality awareness

The operational layer primarily comprises skilled workers and laborers directly engaged in on-site construction. Their skill level and quality awareness are crucial to the project’s quality. Currently, the construction industry still relies heavily on a large, highly mobile labor force, whose level of specialization and professionalism is generally insufficient [9]. Taking concrete pouring as an example, if workers fail to master the timing, frequency, and spacing of vibration, it is very easy to cause quality defects such as honeycomb, pitting, and even voids, which directly affect structural safety. Pan Qianyu found that insufficient operator skills are one of the essential factors that drive up project costs and induce quality hazards. In addition, due to the high mobility of the labor force, it is difficult for them to receive systematic training and guidance, which leads to some construction teams tending to “emphasize efficiency and neglect quality”, thus increasing the difficulty of quality control [4].

#### 2.1.3. Collaboration layer: Information transmission and communication barriers

The collaborative layer, primarily comprising designers, supervising engineers, and on-site managers from subcontractors, plays a crucial role in connecting decision-making and execution and coordinating multi-disciplinary collaboration. Designers have an immense influence on the construction-design coincidence through efficiency and their ability to communicate and coordinate.

Unclear design briefings and the inability to clarify the technical aspects in time can readily cause construction to deviate from the initial design rationale. In complex reinforcement patterns, designers may not be able to interpret them on site, and workers may therefore tend to simplify them, introducing potential hazards into the structures. Furthermore, if the supervising unit fails to establish an effective communication mechanism with the construction team, its supervisory instructions will be difficult to implement during dynamic construction. These issues, stemming from cross-organizational multi-party transmission, lead to information attenuation and collaboration barriers, increasing the risk of human error.

## 2.2. Time Factors

### 2.2.1. The destruction of process quality caused by irrational rush work

To meet tight contract deadlines or make up for earlier delays, construction companies are often forced to take expedited measures, resulting in severe compression of required process time and a failure to implement and guarantee key procedures fully. Taking concrete construction as an example, if the construction company removes the bottom formwork or applies subsequent loads before the concrete reaches the specified strength, it will cause irreversible damage to its long-term durability and structural safety. Cao Yifan found in his research that cost control in building construction is significantly affected by time factors, and unreasonable scheduling arrangements often lead to projects failing to be completed on time and with quality [3]. This practice of prioritizing progress over quality is essentially sacrificing structural safety and functionality in exchange for superficial progress targets. It is a significant failure in project management coordination, which shows that irrational scheduling arrangements directly affect project quality.

### 2.2.2. Chain reactions caused by failure of time planning and control

The cause of the quality problems induced by the time factors is the scientific nature of the construction schedule. When the planning and design phase does not account for all uncertainties, including the material supply cycle and labor resource allocation, and reasonable buffers are not put in place, potential quality problems will creep in at the earliest stages of the project. In the course of implementation, when the construction schedule does not have an effective dynamic monitoring and early warning mechanism, and is not able to promptly notice the schedule deviations and take specific corrective actions, it is simple to enter a vicious circle of relaxed early stages and frantic late stages that is, loose schedule management in early stages of the project, and the amassing of problems, leading to rushed construction in later stages to recover the schedule. It is impossible to ensure the project's quality. This vicious cycle can precipitate a chain of issues, resulting in disordered work processes, simplified inspection processes, and the absence of an overview of covert work, which eventually impacts the quality of the project systemically. Thus, the breakdown of the planning and control system negatively impacts quality management in a significant way.

## 2.3. Geological Environment and Climate Factors

### 2.3.1. Geological conditions and foundation bearing capacity risk

Geological conditions are environmental factors that affect the quality of construction in building projects. Different geological structures, soil layer distributions, and bearing capacity characteristics can affect construction difficulty. Suppose the construction site has unfavorable geological conditions such as soft soil layers, underground karst caves, or backfill soil, and construction is carried out blindly without sufficient investigation and effective foundation treatment. In that case, it is very easy to cause uneven settlement, slippage, or even foundation instability. This can lead to physical quality problems such as elevation errors in the superstructure, cracking of concrete components, and excessive deviations in the installation of precast components, ultimately causing irreversible damage to the overall stability, functionality, and durability of the building.

### 2.3.2. Meteorological conditions and surrounding environmental disturbances

Meteorological conditions and the surrounding environment of the construction site together constitute dynamic external factors affecting project quality. Extreme weather conditions (such as heavy rain, strong winds, and extreme low or high temperatures) not only interrupt construction progress directly and pose higher operational challenges but can also damage semi-finished or finished products, including curing concrete and newly applied waterproofing layers. Therefore, meteorological conditions, by directly affecting construction procedures, processes, and finished products, become variables leading to fluctuations in project quality and potential defects.

Furthermore, if the construction site is near vibration sources (such as rail transit or large equipment) or chemical pollution sources (such as industrial emissions), the continuous vibrations generated may interfere with the compaction and setting process of concrete pouring. At the same time, airborne corrosives may erode steel structures, embedded metal parts, prestressed tendons, and the concrete itself, accelerating their deterioration and posing structural safety hazards, directly affecting the long-term durability and safety of the building project.

## 2.4. Engineering Materials and Equipment Factors

### 2.4.1. Loss of control over the source and process of engineering materials

Material quality is the material foundation of engineering projects. From the mechanical properties of steel and cement to the chemical composition of sand, gravel, and admixtures, any failure to meet key indicators will plant a "time bomb" for the project. Two conspicuous issues are the absence of supplier management and the shallow incoming inspection. In her study of quality control in steel structure, Bian Haihong observed that, the first condition of ensuring the quality of the final product is to strictly control the quality of raw materials used in the components processing, failure to do which will result into the mixing of inferior materials in the site and the subsequent lack of the structure safety and durability of the project [2]. The quality features of the materials directly define the feasibility of the construction process and the quality performance of the final product. Poor-quality materials complicate the task of ensuring quality construction, such as aggregates that fail the gradation test, leading to poor workability of the concrete mix and, in turn, creating defects such as incomplete compaction and honeycomb-like surfaces. Monitoring materials throughout the process, including the source and the site, is required for achieving construction quality that satisfies the design purpose and the intrinsic and aesthetic quality objectives of the project.

### 2.4.2. Potential problems in equipment management and inaccurate status

In contemporary construction work, quality assurance depends heavily on the stable operation of mechanical equipment. The stable development of construction is highly dependent on tower cranes, construction elevators, and other equipment. Not only do the technical state and management conditions influence the construction safety level, but the accuracy of the process implementation and product quality also depend directly on the state of this specific aspect. Poor maintenance or operation, such as malfunctions, may readily cause safety accidents and quality deviations due to poor precision. As an example, interruptions in pouring due to unstable pressure in concrete pumping equipment may lead to quality defects, e.g., cold joints. Guo Ying showed that proper construction techniques and selection of equipment play significant roles in the quality and safety of a complicated project [10]. This is why equipment condition and construction quality, including the precision of equipment such as measuring, cutting, and welding, are closely related. Equipment accuracy defines how accurately the component processing and installation dimensions are. Minor deviations may be increased stepwise in later processes, leading to total quality defects.

### 2.4.3. Risks related to the compatibility of new materials and new processes

The emergence of new materials and processes, such as high-performance concrete and novel composite building materials, has brought new challenges and risks to construction projects. During construction, the characteristics of new materials and specialized construction methods directly impact construction quality. Using traditional methods can easily lead to new quality problems, such as bond failure and shrinkage cracks. Furthermore, in intelligent construction scenarios such as 3D printing and robotic construction, the stability of equipment operation, the accuracy of program settings, and the degree of matching with actual site conditions are all crucial. However, the introduction of these advanced technologies also brings new uncertainties. For example, without sufficient technical reserves and systematic process control, these technologies, which should improve construction quality, may instead become new sources of quality risk.

## 3. Solution

### 3.1. Control Strategies for Human Factors

In response to the complex impact of human factors on construction projects, a comprehensive, systematic, and multi-tiered governance system should be established.

#### 3.1.1. Management empowerment

A quality performance and competency certification system for key positions must be introduced to increase professional competence and accountability of management. The engineering firm may offer training beyond the usual to address problems in current management and to implement a responsibility-accountability system directly associated with individual career development and performance. In the case of core management roles such as project managers, chief engineers, and quality directors, the engineering firm may specify technical qualifications, whose outcomes are directly dependent on being assigned project roles. At the same time, the engineering company can include key indicators, such as quality costs, in the performance appraisals of these staff, thereby creating a quality- and performance-based annual pay system. This makes income depend on the project's quality performance, essentially removing short-sighted behavior that focuses on schedule rather than quality, and clarifying the responsibilities of all personnel in management.

#### 3.1.2. Standardization of operations

To address skill gaps and poor quality standards among on-site workers, a skills-certification system and process benchmarking for construction workers can be adopted. The essence of dealing with these issues is to ensure the industrialization and professionalization of the labor force. In the first place, the practical skills certification system must be adopted for key trades, including steelworkers, concrete workers, and formwork workers, and a compensation system must be provided. Secondly, project managers must decode complex regulations into simple, easy-to-understand operational standards for workers. They can also establish on-site quality benchmark teams, provide on-site training by certified steelworkers and other skilled workers, share best practices via videos and other means, enable rapid replication within the highly mobile labor force, thereby solidifying standardized processes and reducing quality defects caused by improper operation.

#### 3.1.3. Collaborative interconnection

To break down information barriers among collaborating parties, the construction team needs to build a deep collaboration mechanism based on a unified data environment. Project management should focus on building a working environment centered on a unified data model. Simultaneously, industry trends and the inherent need for enterprises to improve quality and efficiency require the comprehensive application of Building Information Modeling (BIM) at the project level—a digital representation and management technology that spans the entire building lifecycle [11]. This model ought to be the sole foundation for all units involved in design briefing, construction simulation, clash detection, and final acceptance, transforming the conventional two-dimensional drawing collaboration into collaborative work based on an accurate three-dimensional model. At the same time, the project management team must develop a digital teamwork process aligned with the model to ensure that all operations, such as design changes, acceptance applications, and problem corrections, are performed and documented online in real time, thereby enabling closed-loop management. Making implicit collaboration between organizations and disciplines explicit and standardized in data processes can reduce misunderstandings of information and ensure a high degree of consistency between construction outcomes and design intent.

## 3.2. Control Strategies for Time Factors

To address the insidious mismanagement of project quality under timeline pressure, a collectivist approach to schedule and quality management needs to be established.

### 3.2.1. Implement flexible schedule planning based on process logic

To overcome the problem of irrational rushing that affects process quality, project management must ensure that timeframes allocated to each process are reasonable from the outset. In particular, during the project's planning phase, management is expected to forego historical data estimation. This approach is associated with low accuracy and limited flexibility in most cases due to the absence of specific process logic and project-specific details. Assume that project management instead embraces BIM-based construction simulation technology to model the entire project process. In such an instance, the project management team will be able to clearly understand the inherent logic and minimum time constraints of instrumental processes, e.g., concrete curing and prestressing tensioning, and apply them as inflexible constraints to a broader plan. Simultaneously, the project schedule should clearly define and dynamically manage quality buffer periods on the critical path to address potential disruptions to key processes caused by unforeseen factors. This approach not only provides operational flexibility for the full implementation of key processes but also provides a scientific basis for ensuring the full implementation of core processes at the legal and contractual levels, preventing irrational rushing that sacrifices quality to meet deadlines.

### 3.2.2. Establish a progress-quality linkage, early warning, and decision-making mechanism

Faced with the chain reaction caused by the failure of time planning and control, project management must break down the information barriers between schedule and quality management. In an integrated project management platform, schedule and quality management milestones are closely linked. When the system detects that the actual progress deviates from the plan, or predicts that a risky period of rushing to meet deadlines is approaching, the system will automatically trigger tiered warnings, simultaneously pushing out specific risks that may arise from the compressed schedule at that stage, as well as checklists and reinforcement measures that must be implemented to ensure quality. Project management can also simultaneously measure schedule and quality risk when making decisions, thereby making decisions more scientifically and comprehensively. This prevents the development of a vicious cycle in which there is relaxed effort in the initial stages and then a rush in the final stages to meet the required quality of construction, so that quality standards are achieved and quality is controlled through dynamic changes.

## 3.3. Management Strategies for Environmental and Climate Factors

To address constraints imposed by objective conditions such as geology and climate, a system of responses can be organized; it is the integrated exploration-monitoring-prevention response system.

### 3.3.1. Implement precise geotechnical investigation and dynamic foundation design

To counteract engineering risks associated with inadequate engineering geological data or insufficient foundation bearing capacity, the project surveying and design departments should consider conducting effective surveys to narrow down uncertainties at an early stage. As an extension of the traditional surveying techniques, the surveying unit is supposed to actively employ equipment like ground-penetrating radar and the high-precision devices involved in drilling to effectively detect the underlying geological structures and soil properties at the construction site, which would then be used to give detailed data to justify the relevant foundation design and construction [12]. On this basis, the project team ought to have a dynamic design and adjustment mechanism.

The foundation treatment scheme (e.g., the length of the piles, the choice of the bearing layer, or its replacement depth) must be dynamically confirmed and optimized based on real-time feedback from monitoring data obtained during construction. For complex geological conditions, the project management should also deploy an automated settlement and displacement monitoring system during the foundation construction phase [13]. This system can analyze and warn of settlement trends in real time, ensuring that the foundation treatment effect is under real-time control, thereby effectively avoiding superstructure quality problems caused by unclear geological conditions or improper treatment.

#### 3.3.2. Establish a proactive prevention and control mechanism for climate and environmental risks throughout the entire process.

The response to meteorological conditions and external environmental disturbances should be upgraded from passive seasonal contingency plans to a proactive, end-to-end prevention and control system. First, the project management team should integrate data from on-site micro-weather stations and regional weather forecasts to establish an adaptive adjustment model for construction processes. This model can directly translate meteorological data into specific operational instructions. For example, the system can predict the optimal time for concrete pouring based on real-time temperature and humidity and recommend matching curing schemes, or automatically trigger instructions and lock high-altitude work equipment under strong wind warnings. Second, for persistent environmental disturbances such as vibration and chemical corrosion, the project technical team should adopt a dual prevention and control strategy combining engineering isolation and material reinforcement [14]. For instance, vibration-isolation trenches should be excavated near vibration sources, and self-compacting concrete should be used for pouring to minimize the impact of vibration operations on the surrounding environment. For steel structures and metal-embedded parts, high-performance anti-corrosion coatings tailored to specific environments should be used to significantly extend the corrosion-resistant lifespan of components and effectively resist chemical erosion. By using key environmental parameters as core input conditions and deeply integrating them into the construction plan decision-making and material selection processes, the project team can achieve proactive control of environmental disturbances at their source, ultimately laying a solid foundation for ensuring the long-term durability of the engineering structure.

### 3.4. Control Strategies for Engineering Materials and Equipment Factors

To ensure the reliability of engineering materials and equipment, it is essential to build a digital traceability and an intelligent operation and maintenance system that covers the entire lifecycle.

#### 3.4.1. Construct a digital material quality traceability system throughout the supply chain

As a solution to the problem of uncontrolled supply of materials at the source and during the process, the departments of project procurement and quality management could shift their post-inspection approach to preventive measures and track the entire process. Businesses or projects are supposed to have stringent mechanisms for accessing suppliers and dynamic evaluation systems in place, along with processes for on-site monitoring of critical structural materials. Moreover, suppliers are required to assign each batch of primary materials a unique QR code digital ID that contains production data, quality certification, reinspection documents, and logistics data. The authenticity of the materials upon arrival can be checked by on-site acceptance personnel by scanning the code with a mobile terminal, and all acceptance standards are automatically retrieved; all acceptance results are archived and uploaded to the system in real-time. This creates a closed material control loop between the factory, the warehouse, and the construction site, allowing project managers to easily and accurately trace where issues originated and who is to blame in the event of quality problems, thereby helping prevent the entry of harmful materials onto the construction site.

### 3.4.2. Implement predictive maintenance for critical equipment based on condition monitoring

To mitigate the risks of equipment management and incomplete equipment status, equipment management departments must extend beyond planned maintenance to include predictive maintenance and upgrades. Project teams can install intelligent sensors on equipment of primary interest to monitor vibration, pressure, and temperature, like tower cranes and concrete pumping systems. These sensors record real-time operational data and send it to a smart operations and maintenance system, enabling continuous monitoring of equipment health. With big data analysis, the platform will detect patterns in equipment performance degradation and issue implicit warnings, transforming maintenance operations into a scientific, on-demand process [15]. At the same time, equipment management departments are supposed to put in place a periodic calibration program for total stations and other high-precision machining equipment, whereby permission to use the equipment is tied to its calibration status to maintain measurement and machining accuracy under control. In this method, process deviation and physical quality defects induced by equipment inaccuracies are removed at their source.

### 3.4.3. Establish a pre-application evaluation and certification for new materials and processes

The technical decision-making level of the project must identify a sound process for introducing and assimilating new materials and methods to mitigate compatibility risks. The project team will have to strictly follow the standardized procedure for conducting a technical feasibility assessment, test phase verification, and developing standardized operating procedures before implementing any new materials, processes, or intelligent construction technologies (3D printing or robotic construction). During testing, the project's technical staff will confirm the suitability of new technologies for the site's specific conditions and issue design-specific instructions for the use of construction methods. The human resources and engineering management departments should then plan to provide specialized training and practical certification for relevant management and operational personnel in accordance with these guidelines. Such a mechanism presupposes that, before the full-scale promotion of new materials and technologies, the skills and management of construction personnel are timely updated, enabling the effective use of new technologies in the construction process, improving quality, and eliminating uncontrollable risks.

## 4. Conclusion

In this paper, the construction stage in engineering project construction is examined, and some factors that affect it are identified. The effectiveness of management systems can be impacted by human factors, which are the prevailing variables. One factor that may affect quality control is time constraints due to unrealistic project timelines. The objective constraints that contribute to high levels of uncertainty and risks to the quality of construction are geological and climatic factors. Materials and equipment form the material base, which influences the project's end quality. To manage these elements, this paper suggests the respective governance directions: mitigating human risks with the assistance of a hierarchical responsibility system and digital training, balancing schedule pressures with the mechanism of progress-quality linkage of early warning, establishing an integrated surveying and prevention mechanism to increase the environmental adaptability, and providing digital traceability and predictive maintenance to guarantee the reliability of materials and equipment. The paper enhances the quality management program during the construction stage of building engineering projects and guides high-quality, sustainable project development.

The way forward for future research in quality management in building engineering projects is towards lean, intelligent, and human-centered quality management. Managers need sharp insight and control skills, with lean thinking as the rational logic and digital technology as an enabler. Finally, by activating the initiative and innovative power of construction staff, they can create a continually evolving, streamlined quality management ecosystem and thus increase the reliability and value of project quality management.

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| **Yes no changes** | √ | **Yes with minor revisions** | | **Yes with major revisions** | | **No** | |
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| **Please expand on any weak areas in the checklist and offer specific advice as to how the author(s) may improve the paper.** | | | | | | | |
| In this paper, you introduce the reasons and solutions for improving quality and reducing risks in building construction. However, there are several issues, such as incorrect word usage and author names. The main problem lies in the titles: many third-level headings are followed by only a short paragraph, which weakens the structure. I suggest deleting all third-level titles to make the paper more concise and coherent. | | | | | | | |