Research on the Application of Optimization Methods of Network Planning Technique in Construction Management of Building Engineering

Zaijun Tao

Anhui Yushu Construction Engineering Co., Ltd., Hefei, Anhui, 230000, China

Keywords: Network Planning Technique; Building Engineering; Construction Management; Duration Optimization; Resource Allocation

Abstract: Against the backdrop of the continuous expansion in the scale of building engineering projects and their increasingly complex structures, traditional experience-based construction management has found it challenging to meet the complex requirements of multi-process coordination, resource allocation, and cost control over project duration. During the construction process of building engineering projects, leveraging network planning technique to effectively manage the construction process can enhance the economic efficiency of building engineering and reduce unnecessary cost expenditures through an analysis of the project's construction schedule. This paper takes network planning technique as the core research object, systematically reviews its key methods and implementation logic, and proposes multi-dimensional application optimization strategies in conjunction with the entire process of construction management in building engineering, aiming to provide practical references for enhancing the level of refinement in construction management of building engineering.

1. Introduction

In recent years, the building engineering industry in China has witnessed a rapid development phase, with an increasing number of complex projects such as super high-rise buildings, large-scale complexes, and transportation hubs emerging year by year. These projects generally feature long construction periods, numerous overlapping processes, substantial resource demands, and challenging cost control, posing higher requirements for the systematic and scientific nature of construction management. As a project management tool based on mathematical logic and system analysis, network planning technique has gradually become an important means to address pain points in construction management since its introduction into the field of building engineering, thanks to its visual representation of construction tasks, clear organization of logical relationships, and multi-dimensional optimization capabilities.

2. Core Optimization Methods of Network Planning Technique

2.1 Focusing on Critical Path and Precisely Compressing Critical Activities

Duration optimization aims to shorten the total project duration or meet the contractually agreed-upon duration while ensuring compliance with construction processes and quality safety. The core lies in identifying the "critical path" in the network plan—the sequence of activities with the longest total duration that directly determines the project's total duration. The optimization logic proceeds in three steps: First, calculate the "four time parameters" for each construction activity—earliest start time, earliest finish time, latest start time, and latest finish time—to screen out activities with zero total float and form the critical path, thereby identifying the core objects for optimization. Second, prioritize the selection of critical activities with a "high cost-effectiveness ratio for compression," focusing on activities with a large proportion of duration, minimal resource investment required for compression, and minimal impact on subsequent processes to avoid management chaos caused by blind compression. Finally, strictly control the compression boundaries to prevent quality risks arising from excessive compression of activity durations, while

  DOI: 10.25236/icacel.2025.192

dynamically checking whether new critical paths emerge after compression. If new critical paths are generated, simultaneous optimization is required to ensure no loopholes in duration control. During implementation, compression plans should be formulated in conjunction with construction process logic, and professional software should be used to replace manual calculations to enhance the precision of compression effects and avoid optimization failure due to calculation errors [1].

2.2 Balancing Duration and Cost to Identify the "Lowest-Cost Duration"

The core of cost optimization is to resolve the associated conflict between duration and cost in building engineering—shortening the duration requires increased resource investment to enhance efficiency, leading to a rise in direct costs such as labor, materials, and machinery; extending the duration increases indirect costs such as project management fees and capital occupation interest. The optimization focuses on identifying the "lowest-cost duration," the duration node with the lowest total cost. The optimization logic revolves around three aspects: First, establish a cost-duration correlation curve by relying on historical project data and industry quota standards to compile statistics on direct and indirect costs corresponding to different durations, clarifying the pattern of increasing direct costs and decreasing indirect costs as the duration shortens. Second, locate the lowest point of the total cost by superimposing the direct cost curve and the indirect cost curve to determine the "lowest-cost duration." Third, dynamically adjust for deviations between the contract duration and the "lowest-cost duration." If the contract duration is shorter than the "lowest-cost duration," prioritize the selection of critical activities with the lowest unit-time compression cost for gradual compression to control the increase in total cost; if the contract duration is longer than the "lowest-cost duration," adjust the pace of non-critical activities to reduce resource idleness and lower indirect costs. During implementation, distinguish between controllable and uncontrollable costs, prioritize the optimization of controllable costs such as machinery rental time and labor scheduling, and leverage intelligent software to achieve visual linkage analysis of cost and duration to enhance the scientific nature of optimization plans.

2.3 Resolving Supply-Demand Conflicts to Achieve Balanced Resource Allocation

Resource optimization targets the supply-demand imbalance of resources such as labor, machinery, and materials in building engineering, categorized into "resource-constrained—shortest duration" and "fixed duration—balanced resources." The core is to utilize the free float and total float of non-critical activities to match resource demand with supply and improve resource utilization efficiency. Taking "fixed duration—balanced resources" as an example, the optimization logic proceeds in three steps: First, draw a resource demand curve by compiling statistics on daily or weekly resource demand during the planned period to identify peak and trough periods of resource demand. Second, adjust the timing of non-critical activities by shifting non-critical activities during peak resource demand periods to trough periods to smooth the resource demand curve and avoid supply-demand conflicts caused by concentrated resource occupation. Third, establish a resource allocation priority by prioritizing the resource demand for critical activities if resource gaps still exist, and adjusting non-critical activities in descending order of total float to prevent resource shortages from affecting the total duration. During implementation, construct a "resource-activity" correspondence table to clarify the type and quantity of resource demand for each activity, while leveraging Internet of Things technologies such as RFID material tracking and tower crane positioning systems to collect real-time resource usage data and dynamically adjust allocation plans through professional software to ensure that resource optimization aligns with construction progress.

3. Implementation Path of Network Planning Technique Optimization in Construction Management of Building Engineering

3.1 Preliminary Preparation: Constructing an Accurate Basic Network Plan Model

Preliminary preparation is the prerequisite for optimizing network planning technique, with the core being the establishment of a basic model that aligns with the actual project conditions to provide reliable data support for subsequent optimizations. First, decompose construction tasks according to the hierarchy of "project—unit project—sub-project—sub-item project" to break down the overall project into specific, operable work items, clarifying the scope and content of each work item to avoid logical confusion in the model caused by ambiguous task decomposition. Second, organize the logical relationships between work items, distinguishing between "predecessor activities" and "successor activities" to clarify process sequence requirements and ensure a complete and compliant logical chain. Finally, estimate work parameters by relying on industry quota standards, enterprise historical project databases, and technical disclosure documents to determine the duration, resource demand (types and quantities of labor, machinery, and materials), and cost consumption for each work item. Parameter estimation should balance reasonableness and precision to avoid affecting subsequent optimization results due to data deviations. During this process, validate the basic model data by communicating with technical, cost, and construction departments to ensure that task decomposition, logical relationships, and parameter estimation align with the actual project conditions.

3.2 Optimization Calculation: Selecting Appropriate Methods to Output Scientific Optimization Plans

Optimization calculation is the core link for realizing the value of network planning technique, requiring the selection of appropriate methods in conjunction with project control objectives and the use of professional tools to enhance optimization efficiency and precision. First, clarify the priority of optimization objectives. If project duration control is the core, prioritize the use of the critical path compression method; if cost control is the focus, concentrate on solving for the "lowest-cost duration"; if resource constraints are significant, emphasize balanced resource allocation optimization. For scenarios with multi-objective coordination requirements, determine objective weights to provide direction for multi-objective optimization. Second, select professional tools and algorithms to replace traditional manual calculations. Commonly used tools include project management software such as Project and Primavera P6, which can automatically identify critical paths and simulate the effects of different optimization plans. For multi-objective optimization scenarios, introduce intelligent algorithms such as genetic algorithms and particle swarm optimization to solve for Pareto optimal solutions through software and screen plans that meet project requirements. Finally, validate and adjust the plan by conducting feasibility checks on the preliminary optimization plan from dimensions such as construction processes, resource supply, and cost budgets to assess whether the plan can be implemented. If conflicts exist (e.g., resource allocation exceeds actual supply capacity), return to adjust optimization parameters until a scientific and feasible final plan is formed, thereby clarifying optimization measures, implementation steps, and expected effects during the calculation process to provide a basis for subsequent execution.

3.3 Dynamic Control: Adjusting Optimization Plans in Conjunction with Actual Construction Conditions

Construction of building engineering projects is susceptible to external factors, and dynamic control is key to ensuring the continuous effectiveness of optimization plans, requiring the establishment of a dynamic mechanism of "tracking—analysis—adjustment." First, track construction progress and resource cost data in real-time by collecting actual data, including the actual completion time, actual resource consumption, and actual cost expenditure for each work item, through on-site inspections and collaborative management platforms to ensure timely and accurate data collection. Second, compare and analyze deviations by contrasting actual data with planned data to identify deviations in progress, resources, and costs and determine whether the work item with deviations is a critical activity. If it is a critical activity deviation, assess the impact on the total duration and total cost; if it is a non-critical activity deviation, check whether the total float has been consumed to avoid conversion into a critical activity deviation. Finally, formulate corrective measures and update the model by developing targeted measures based on the causes of deviations, adjusting work parameters and optimization plans according to the corrective measures, and updating the network plan model to ensure alignment with actual construction conditions. During this process, establish a regular review mechanism to summarize dynamic control conditions on a weekly or monthly basis, analyze deviation patterns, and optimize subsequent control priorities [2].

4. Application Optimization Strategies for Network Planning Technique Optimization Methods in Construction Management of Building Engineering

4.1 Consolidating Data Foundations: Establishing a Standardized Data Management System

Data accuracy is the core prerequisite for optimizing network planning technique, requiring the resolution of issues such as parameter estimation deviations and insufficient data sharing through a standardized data management system. By constructing an enterprise-level project database, integrate information such as construction task decomposition standards, work durations, resource consumption quotas, and cost accounting data from historical projects, and categorize and store it by project type to provide data references for network plan modeling in new projects and avoid deviations caused by reliance on experience-based estimation. Meanwhile, formulate data collection and validation standards to clarify the scope, frequency, and responsible entities for data collection at each construction stage, adopt a "on-site collection + system entry" approach to ensure data timeliness, and safeguard data authenticity through cross-validation by technical, cost, and construction departments. On this basis, build a data sharing platform to break down data barriers across project management links and achieve data interoperability between the network plan model and progress management, cost management, and resource management systems to ensure that optimization plans can be adjusted with real-time access to the latest data and enhance the accuracy of optimization decisions.

4.2 Strengthening Personnel Capabilities: Constructing a Tiered Professional Training Mechanism

The proficiency of management personnel in network planning technique directly influences its application effectiveness, necessitating the enhancement of team professional capabilities through tiered training. For frontline construction management personnel, conduct basic operational training focusing on topics such as network plan diagram interpretation, critical path identification, and progress deviation judgment to enable them to understand optimization plans and implement them in on-site construction. For mid-level technical management personnel, provide advanced application training covering topics such as network plan model construction, optimization method selection, and professional software operation to enable them to lead the formulation and dynamic adjustment of network plan optimization plans. Finally, for senior management decision-makers, offer strategic cognitive training to emphasize the value of network planning technique in project control and enhance their level of importance towards its application, thereby promoting resource investment and institutional support at the enterprise level. During the training process, establish a training assessment and incentive mechanism by incorporating network planning technique application capabilities into personnel performance evaluations and encouraging management personnel to actively learn and practice, forming a closed loop of "training—application—assessment" to effectively enhance the quality and effectiveness throughout the entire building construction lifecycle [3].

4.3 Promoting Technological Integration: Deepening the Synergy between Network Planning and Emerging Technologies

To overcome the limitations of traditional network planning technique applications, it is necessary to construct a deep synergy system between network planning and emerging technologies based on the actual needs of construction management in building engineering, enhancing the dynamism and precision of optimizations. By deepening the scenario-based integration with BIM technology and leveraging the three-dimensional visualization and parametrization characteristics of BIM models, associate each sub-item work in the network plan with model components to achieve spatial visualization of construction progress, facilitating the intuitive identification of spatial conflicts caused by multi-process overlaps and providing spatial dimensional support for resource allocation optimization. Meanwhile, utilize BIM's simulation capabilities to pre-simulate the construction process for network plan optimization plans, proactively identifying issues in the plan that are inconsistent with construction processes and site conditions to reduce on-site adjustment costs. On this basis, explore the adaptive application of intelligent algorithms in multi-objective optimization. For the complex needs of multi-objective coordinated optimization of "duration—cost—resources" in building engineering, select appropriate intelligent algorithms in conjunction with specific project constraints, achieve algorithm "connection" with network plan software through programming, construct a multi-objective optimization calculation model, automatically solve for optimal plan sets that meet constraint conditions, and then combine the experience and judgment of project management teams to screen for plans that best align with actual construction needs, thereby enhancing optimization efficiency while ensuring plan feasibility [4].

5. Conclusion

As a core tool for construction management in building engineering, the depth and breadth of the optimized application of network planning technique directly influence project control effectiveness. With building engineering projects advancing towards supersized, complex, and intelligent directions, traditional management models reliant on experience have found it difficult to meet the demands of multi-objective coordinated control. The optimized application of network planning technique has become a key support for driving the transformation of construction management from "extensive" to "refined." In the future, with the continuous development of technologies such as intelligent algorithms and digital twins, network planning technique is expected to achieve an upgrade from "passive optimization" to "active prediction," providing more comprehensive and efficient technical support for construction management in building engineering and contributing to the enhancement of overall industry management levels.

References

[1] Cui Xudong. Application of Network Planning Technique in Construction Management of Building Engineering[J]. Building Materials & Decoration, 2018, (31): 293-294.

[2] Huang Xiaolan. Application of Network Planning Technique in Construction Management of Building Engineering[J]. Jiangxi Building Materials, 2017, (10): 297+299.

[3] Bao Huiru. Research on the Application of Optimization Methods of Network Planning Technique in Construction Management of Building Engineering[J]. Private Science and Technology, 2017(2): 80.

[4] Zhang Yingfeng. An Analysis of the Application of Network Planning Technique in Construction Management of Building Engineering[J]. Shandong Industrial Technology, 2016(17): 91.