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# Practice and Exploration of Critical Path Management from the Perspective of Total Construction Period

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**Abstract:** This article focuses on the overall construction duration, explaining the core role of the critical path method and its relationship with the total construction period. It analyzes the factors influencing the total construction duration, introduces the application of BIM and other technologies in identifying and managing critical paths, emphasizes the importance of optimizing resource allocation, and illustrates measures to address disruptions through practical examples. Additionally, it discusses the evaluation system and incentive mechanisms.

**Keywords:** Total construction period; Critical line; Resource allocation

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## 1. Introduction

In the field of project management, Critical Path Method (CPM) has been a core technology since its inception in the 1950s. The total construction period is influenced by multiple factors such as process connection, resource supply, and external environment. For example, the "Regulations on Quality Management of Construction Projects" issued in 2020 emphasize that the construction process should comply with relevant standards to ensure the smooth progress of the project, among which period management is a key part. BIM modeling and progress monitoring system, as well as optimization of resource allocation on critical routes, play an important role in the overall construction period. In engineering examples such as municipal roads and cross sea bridges, factors such as weather and tides affect key routes and the overall construction period, and corresponding measures need to be taken. Meanwhile, Monte Carlo simulation and progress warning mechanisms also play a role in ensuring the overall construction period, while critical path management has limitations, and digital twin technology and intelligent decision support systems provide development directions.

## 2. Theoretical basis of critical path management

### 2.1. Basic principles of critical path method

The Critical Path Method (CPM) is a cornerstone of modern project planning, conceived in the late 1950s by DuPont and Remington Rand to curtail chemical-plant downtime [1]. It has since evolved into a universal language for engineers, architects, and IT managers who must orchestrate thousands of interdependent tasks. CPM begins by decomposing the project into discrete activities, each defined by a crisp scope, estimated duration, and precedence logic. These activities are then woven into a time-scaled network diagram whose nodes denote start or finish events and whose arrows embody both workflow and elapsed time. The algorithm proceeds in two passes: a forward pass establishes earliest start and finish times, while a backward pass computes latest allowable moments without slipping the contractual end date. Activities with zero total float—where earliest and latest times coincide—constitute the critical path, the project's longest duration route from kickoff to closeout. Because this path has no scheduling cushion, any slippage, however small, propagates directly into project completion; conversely, acceleration of critical tasks compresses overall duration. Managers therefore monitor the critical path with heightened vigilance, reallocating labor, authorizing overtime, or fast-tracking parallel work to absorb emerging delays. As the project unfolds, actual progress is compared against baseline dates, and the network is re-analyzed to reveal newly critical activities. This dynamic feedback loop transforms CPM from a static plan into a living control system that synchronizes resources, budgets, and stakeholder expectations with the immutable rhythm of the critical path.

### 2.2. Composition elements of the total construction period

The total construction period consists of multiple elements. Process connection is one of the key factors, and the sequence, duration, and logical relationship between each process directly affect the overall construction period. Reasonably arranging processes, ensuring tight connections, and avoiding delays or disconnections in processes are the foundation for ensuring the overall construction period [2]. The supply of resources also has a significant impact on the overall construction period, including the adequacy and timeliness of resources such as manpower, materials, and mechanical equipment. If the supply of resources is insufficient or not timely, it may lead to process stagnation and prolong the overall construction period. The external environment cannot be ignored, such as weather conditions, policies and regulations, and the surrounding social environment. Adverse weather conditions may hinder construction progress, changes in policies and regulations may require adjustments to construction plans, and disturbances from the surrounding social environment may also affect construction efficiency, thereby affecting the overall construction period.

## 3. Analysis of the transmission path of critical path management to the total construction period

### 3.1. The impact of dynamic recognition technology

BIM-driven 4D/5D modeling, seamlessly integrated with cloud-enabled progress-monitoring systems, has revolutionized the dynamic identification of critical paths, delivering an efficiency leap that eclipses legacy manual recognition. By generating an intelligent, object-oriented 3D model enriched with time and cost dimensions, BIM visualizes every structural element, temporary facility, and logical dependency in a single, coherent environment [3]. Schedule data imported from Primavera or MS Project are instantly linked to model objects, enabling automated forward- and backward-pass calculations that pinpoint the critical path with millimetric precision. IoT sensors, drone photogrammetry, and mobile field apps continuously stream real-time quantities, percent-complete metrics, and resource utilization into the common data environment. Machine-learning algorithms then compare actual versus planned progress, instantly recalculating float values and flagging emerging critical sequences that manual methods would detect only days later. This closed-loop feedback empowers managers to simulate “what-if” scenarios—such as resequencing crane lifts, reallocating crews, or fast-tracking parallel trades—before delays propagate. By eliminating human latency and subjective judgement, the technology prevents cascading slips, safeguards milestone commitments, and sustains optimal resource flow along the ever-shifting critical route, thereby securing on-time project delivery while enhancing cost predictability and stakeholder transparency.

### 3.2. Optimization effect of resource allocation

The optimization of resource allocation on the critical path has a significant impact on the overall construction period. By allocating resources reasonably, the processes on the critical path can be executed more effectively. The multi-objective optimization model can verify the compression effect of resource dynamic scheduling on the duration of critical line processes [4]. When resource allocation is optimized, the manpower, material resources, and financial resources required for the process can be supplied in a timely and sufficient manner, thereby avoiding project delays caused by resource shortages. Meanwhile, dynamic scheduling of resources can be flexibly adjusted according to the actual progress of the process, ensuring efficient utilization of resources. This optimization effect of resource allocation propagates along the critical path, ultimately having a positive impact on the overall project duration, achieving a reduction in the overall project duration and an improvement in the overall project benefits.

## 3. Case Analysis of key line management practice

### 3.1. Example of municipal road engineering

#### 3.1.1. Project overview and schedule

This municipal road engineering example includes [specific quantity] roads, with a total length of [X] kilometers and a design speed of [specific speed]. The project covers multiple disciplines such as road engineering, bridge engineering, and drainage engineering. The project team prepares an initial progress network diagram based on the project contract schedule requirements, construction drawings, construction techniques, and actual site conditions. The contract duration is [specific duration], which is determined taking into account the travel needs of surrounding residents and urban development planning. The construction drawings provide detailed specifications for the dimensions, materials, and technical requirements of each part of the project, providing precise work content for the schedule. The construction process determines the sequence and logical relationship of various tasks. The actual situation on site includes terrain and topography, distribution of underground pipelines, etc. These factors have a significant impact on the construction sequence and resource allocation. Taking into account the above factors comprehensively ensures the scientificity and rationality of the schedule plan [5].

#### 3.1.2. Key path optimization process

In the example of municipal road engineering, weather has caused interference with construction. For example, the rainstorm weather may cause the subgrade construction to be unable to proceed normally, and some processes on the original key lines will be forced to delay. At this time, adjustments have been made to the route, and the construction process of ancillary facilities that are less affected by weather, such as the pouring of street lamp foundations, has been advanced. At the same time, temporary drainage facilities have been added to reduce the soaking time of rainwater on the roadbed and ensure that subsequent construction can be restored as soon as possible. Through these measures, although the critical path has changed, the construction period has been effectively controlled, and the overall construction period can still meet the requirements. This reflects the importance of flexible adjustment according to actual situations in critical path management, and also provides reference experience for similar projects when facing weather disturbances [6].

## 3.2. Cross sea bridge construction project

### 3.2.1. Analysis of marine environmental impact

Tidal changes are an important factor in the marine environment and have a significant impact on the critical path of water operations on cross-sea bridges. The periodic fluctuations of tides cause changes in water levels, affecting the construction time window for water operations such as pile driving and hoisting. In some critical processes, such as the installation of large prefabricated components, it must be carried out under specific water level conditions. Tidal changes may delay or advance the appropriate installation time, leading to critical path deviation. This offset may trigger a chain reaction in subsequent processes, affecting the overall project timeline. Therefore, in the management of critical routes, it is necessary to accurately quantify the impact of tidal changes, establish a tidal prediction model, and adjust the time schedule of key processes reasonably in combination with construction plans to ensure the stability of critical routes and ensure the smooth progress of cross-sea bridge construction projects [7].

### 3.2.2. Implementation of emergency management strategies

In the construction project of a cross-sea bridge, simulating emergency response plans under sudden wind weather is crucial for ensuring the overall construction period. Sudden wind weather may cause construction delays, equipment damage, and other situations, affecting operations on critical routes. By simulating sudden wind weather, develop targeted emergency response plans, including measures for personnel evacuation, equipment fixation, and protection [8]. In the event of sudden gusts of wind, it is possible to quickly follow the plan and reduce losses and delays. At the same time, the emergency response plan also considers subsequent recovery construction measures to ensure that operations on critical routes can be restarted as soon as possible, maximizing the protection of the overall construction period from the serious impact of sudden wind weather and maintaining the overall progress of the project.

# 4. Construction period optimization strategy and management system construction

## 4.1. Design of progress warning mechanism

### 4.1.1. Risk threshold setting method

Monte Carlo simulation is an effective risk analysis method that can be used to establish schedule deviation warning standards. By simulating the duration of project activities multiple times, the possible distribution of project duration can be obtained. Based on this distribution, determine the progress deviation threshold for different risk levels. For example, at a lower risk tolerance, setting a smaller progress deviation threshold is necessary for timely warning and taking measures. At the same time, focusing on the impact of schedule deviations in key activities on the overall project timeline, taking into account the critical path of the project. Considering various uncertain factors in the project, such as changes in resource supply and weather conditions, Monte Carlo simulation can more accurately reflect the actual situation, provide scientific basis for setting risk thresholds, and effectively construct a progress warning mechanism to ensure that the project proceeds as planned [9].

### 4.1.2. Optimization of early warning response process

The progress warning mechanism is crucial during the construction process. When there is a schedule deviation, a three-level linkage response mechanism, including the owner, supervisor, and construction party needs to be designed. Firstly, a fast and effective information transmission channel should be established to ensure that all parties can obtain warning information in a timely manner. The construction party, as the main body of on-site implementation, quickly analyzes the reasons and proposes preliminary solutions after receiving warnings, and reports to the supervisor at the same time. The supervisor reviews and evaluates the construction party's plan, provides professional opinions, and jointly reports to the owner with the construction party. The owner makes decisions based on the opinions of all parties and coordinates resources to support the construction party in adjusting the schedule. Through this three-level linkage response mechanism, all parties clarify their responsibilities, collaborate efficiently, and minimize the risk of project delays, ensuring that the project progresses as planned [10].

## 4.2. Dynamic resource allocation system

### 4.2.1. Multi-project resource sharing platform

Building a regional construction resource scheduling database is the foundation for achieving dynamic resource allocation and multi-project resource sharing. The database should cover detailed information on various construction resources, such as quantity, location, usage status, etc. Meanwhile, the design of intelligent matching algorithms is crucial. Through algorithms, suitable resources can be quickly and accurately matched based on project requirements and resource status. For example, when a project urgently needs specific equipment on a critical path, the algorithm can search and recommend available resources in the database. This not only improves the efficiency of resource utilization, avoids resource idle and waste, but also ensures the timely progress of construction tasks on key routes, thereby optimizing the overall construction period.

### 4.2.2. Practice of flexible employment system

During the construction process, key procedures often face labor shortages. The time-sharing employment system is an effective solution. By analyzing the work intensity and labor demand during different time periods, arrange workers' working hours reasonably. For example, for some critical processes that are non-continuous but have a significant impact on the overall construction period, flexible working hours can be adopted to avoid peak periods of labor demand. Meanwhile, utilizing modern information technology to dynamically monitor and allocate labor resources. According to the progress of the process, adjust the employment arrangement in a timely manner to ensure the smooth progress of key processes. In addition, it is necessary to establish corresponding incentive mechanisms to improve the work enthusiasm and efficiency of workers under the time-sharing employment system, thereby alleviating the shortage of labor in key processes and ensuring the overall construction period.

## 4.3. Construction period assessment and evaluation system

### 4.3.1. Design principles for KPI indicators

From the perspective of the overall construction period, the design of KPI indicators should follow certain principles. In critical path management, the design of KPI indicators for the assessment system should comprehensively consider multidimensional factors such as progress deviation rate and resource turnover rate. From the perspective of schedule deviation rate, it is important to ensure that the indicators accurately reflect the degree of deviation between actual progress and planned progress, in order to promptly identify and adjust issues. For resource turnover rate, it is necessary to measure the efficiency of resource utilization during the construction process, in order to avoid resource idleness or waste. The indicator design should be scientific and objectively reflect the construction status. It should be operable, easy to collect, and analyze data. At the same time, there should be guidance to motivate the construction team to optimize schedule management and strive towards efficient utilization of resources and ensuring progress.

### 4.3.2. Optimization plan for incentive mechanism

To optimize the construction period, it is necessary to establish a reasonable assessment and evaluation system and an incentive mechanism. In terms of the assessment and evaluation system, clear schedule indicators should be set, including the completion status of each process on the critical path. Accurately evaluate the construction progress by comparing and analyzing the actual and planned construction periods. At the same time, considering the impact of factors such as quality and safety on the construction period, comprehensively evaluate the performance of the construction team.

In the optimization plan of the incentive mechanism, material rewards such as bonuses, prizes, etc. will be given to teams that complete critical process lines on time or ahead of schedule to increase their enthusiasm. For situations where the project schedule is delayed, appropriate penalties should be imposed, such as deducting a portion of the project payment. Honorary awards can also be established to recognize teams with excellent project management, enhance their sense of honor and responsibility, and motivate construction teams to actively participate in project optimization work from both material and spiritual perspectives.

## 5. Conclusion

Critical path management plays a core role in compressing the total construction period. It effectively avoids project delays by precisely controlling the construction process and arranging various procedures reasonably. However, current research has limitations in data processing accuracy, which to some extent affects the effectiveness of critical path management. With the development of technology, digital twin technology provides a possible direction for the dynamic simulation of construction progress. Through this technology, the construction process can be simulated more accurately, improving the management level of critical routes. Meanwhile, intelligent decision support systems have shown promising application prospects in large-scale complex engineering projects. It can comprehensively analyze various data, provide scientific basis for construction decision-making, further optimize key line management, and better achieve the goal of compressing the total construction period.

## Disclosure statement

The author declares no conflict of interest.

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