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Improving Schedule Performance in Data Center Construction Using Critical Path Analysis: An Applied Project Scheduling Perspective at Clune Construction

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ABSTRACT

Data center construction projects are characterized by complex activity interrelationships, high coordination requirements, long lead equipment, specialized mechanical and electrical systems, and demanding completion timeframes. These characteristics place significant responsibility on project schedulers to identify schedule driving activities, track schedule changes, evaluate delay impacts, and support project responses within a narrow schedule control window. This paper explores how Critical Path Analysis (CPA) can be used to improve schedule performance within the context of Clune Construction's project scheduling practice. Clune Construction's mission critical practice specializes in data center projects, where early planning, particularly procurement planning, deliberate activity sequencing, phased turnover, commissioning, and a structured schedule control approach all contribute to project delivery. A narrative literature review with thematic synthesis was conducted based on 26 selected sources covering critical path analysis, construction scheduling, schedule risk, resource allocation and optimization, data center construction, and technology enabled project management. Critical Path Analysis was found to provide a systematic means of identifying activities that influence project completion, establishing relationships between project activities, identifying schedule float, and tracking schedule changes that affect the critical path. It was also found that activity duration shifts, procurement and supply chain limitations, resource availability, coordination needs, project and activity complexity, and execution risk are associated with schedule performance. For a project scheduler, the practical benefit of CPA therefore extends beyond establishing a baseline schedule to include continuous schedule monitoring, critical path reassessment, risk identification, resource prioritization, and corrective action planning. Based on the reviewed literature and the practical requirements of data center construction, the article proposes a framework linking project planning, activity sequencing, critical path analysis, continuous monitoring and risk analysis, resource prioritization, corrective action, and improved schedule performance. The article concludes that CPA can serve as a practical schedule control mechanism for data center construction when continuously updated and integrated with procurement, coordination, resource management, and complementary project management practices.

1. Introduction

Data center construction is a highly integrated form of mission critical construction that requires building systems, mechanical systems, electrical systems, controls, information technology infrastructure, testing, commissioning, and turnover to occur on tightly controlled schedules. Clune Construction, a heavy industrial specialty contractor, describes mission critical construction as involving early mechanical, electrical, and plumbing (MEP) coordination, procurement planning, constructability planning, intentional sequencing, phased turnover, concurrent scheduling, quality control, and commissioning, all of which make schedule management a vital concern for project teams delivering data center projects on aggressive schedules.

Scheduling is crucial in data center projects because many construction activities are interdependent. This becomes particularly important when a delay in one activity affects successor activities that depend on it. Menesi (2010) states that 'CPA provides the theoretical framework for listing activities and the controlled sequence of events of project duration,' while Poliani (2019) states that 'CPM is just part of an overall construction planning and control systems.' Moreover, Hammad et al. (2020) show that variations in activity duration can result in changes to the critical path, meaning that the sequence of critical activities may not remain fixed throughout the project duration.

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The practical importance of this issue is evident in data center construction, where procurement and equipment delivery can directly affect construction activities. Clune has documented challenges involving long equipment lead times, material delays, vendor coordination, and changes in equipment availability. Its published experience indicates that procurement information needs to be connected to the construction schedule and that alternative solutions may be required when delays threaten project milestones.

For a project scheduler, these conditions create a need to move beyond simply developing an initial baseline schedule. The scheduler must identify activities that can influence project completion, monitor changes to activity durations and dependencies, assess emerging schedule risks, communicate their potential effects, and support the project team in determining appropriate corrective actions. CPA provides a structured mechanism for performing these functions because it establishes relationships between activities and identifies activities with limited or no available float (Menesi, 2010; Hammad et al., 2020).

Resource availability is another important consideration. Construction scheduling does not occur independently of labor, materials, equipment, subcontractors, and site conditions. Agumalu (2021) identifies resource allocation and project planning as important components of project management, while Doostali et al. (2021), Lal and Rama Krishna (2018), and Zhang et al. (2020) demonstrate how critical path information can be incorporated into scheduling and optimization decisions in computing environments. Although these studies are not specifically based on construction projects, their treatment of critical activities, dependencies, deadlines, and resource related scheduling provides useful supporting perspectives.

The application of CPA can therefore be particularly relevant to the work of a project scheduler in data center construction. Instead of viewing the critical path only as a calculation performed during schedule development, it can be used as a continuing schedule control mechanism. The scheduler can use changes in the critical and near critical activities to determine where increased monitoring, coordination, resource attention, procurement intervention, or recovery planning may be required.

This article therefore examines the application of Critical Path Analysis to improve schedule performance in data center construction, using the project scheduling environment of Clune Construction as the practical context. The article focuses on the relationship between activity sequencing, critical path identification, schedule monitoring, schedule risk, resource prioritization, and corrective action. It develops a conceptual framework showing how these elements can be connected to support more effective schedule control in data center construction.

1.1 Problem Statement

Data center construction projects require the coordination of numerous activities involving multiple trades, specialized systems, equipment suppliers, subcontractors, and testing and commissioning requirements. Clune's documented data center experience illustrates the importance of procurement, equipment leads times, MEP coordination, vendor communication, and schedule management in maintaining project progress.

The difficulty is that the activities affecting project completion can change as construction progresses. Hammad et al. (2020) show that changes in activity durations can alter the critical path, while Menesi (2010) demonstrates the importance of considering schedule flexibility and activity relationships in construction scheduling. Consequently, a schedule that correctly identifies the critical path at the beginning of a project may require reassessment when procurement delays, resource changes, design changes, coordination problems, or execution constraints occur.

For a project scheduler, the problem is therefore not simply to produce a schedule but to maintain useful schedule information throughout project execution. Without continuous analysis, changes affecting critical or near critical activities may not receive sufficient attention until they have already affected subsequent work.

The problem addressed by this article is therefore the need for a practical approach through which Critical Path Analysis can support continuous schedule monitoring, identification of schedule risks, resource prioritization, and corrective action planning in data center construction. The article addresses this problem within the practical context of Clune Construction's mission critical construction environment without claiming access to confidential internal project data.

1.2 Aim of the Article

The aim of this article is to examine how Critical Path Analysis can be used to improve schedule performance in data center construction from a project scheduling perspective, using Clune Construction as the practical organizational context.

1.3 Objectives

The objectives are to:

1. Examine the application of Critical Path Analysis in data center construction scheduling.

2. Identify factors that can influence schedule performance in data center construction.
3. Examine how critical path identification can support schedule monitoring and delay management.
4. Assess how critical path information can support resource prioritization and corrective action planning.
5. Develop a conceptual framework showing how Critical Path Analysis can contribute to improved schedule performance in data center construction.

1.4 Research Questions

1. How can Critical Path Analysis be applied to data center construction scheduling?
2. What factors influence schedule performance in data center construction?
3. How can critical path identification support schedule monitoring and delay management?
4. How can critical path information support resource prioritization and corrective action?
5. How can Critical Path Analysis be integrated into a practical schedule control framework for data center construction?

1.5 Significance of the Article

The article is significant because it connects the theoretical application of Critical Path Analysis with the practical responsibilities of project scheduling in data center construction. For project schedulers, the framework provides a structured way of thinking about the relationship between activity sequencing, critical activities, schedule risk, resource decisions, and corrective action.

For project managers and construction teams, the framework can support communication around activities that have the greatest potential influence on project completion. For researchers, the article provides a basis for further investigation of CPA in mission critical construction environments.

The Clune Construction context is particularly useful because the company's published material demonstrates the practical importance of procurement, MEP coordination, vendor communication, phased delivery, and schedule management in data center projects.

1.6 Scope of the Article

The article focuses on Critical Path Analysis and schedule performance in data center construction. The discussion covers activity identification and sequencing, critical path determination, schedule monitoring, schedule risk, resource prioritization, procurement related schedule considerations, and corrective action.

The practical context is Clune Construction's mission critical/data center construction environment. However, the article does not present confidential Clune project information, proprietary schedules, internal performance data, or interviews as empirical evidence. Instead, publicly documented information about Clune's data center construction practices is used to establish the practical context, while the main analytical foundation is provided by the reviewed academic literature.

1.7 Methodology

This article adopts a narrative literature review with thematic synthesis. Twenty-six relevant sources were reviewed and organized around the major themes of Critical Path Analysis, construction scheduling, schedule performance, schedule risk, resource allocation, scheduling optimization, data center construction, and technology enabled project management.

The literature was examined to identify recurring relationships between critical activities, activity dependencies, schedule flexibility, changes in the critical path, resource constraints, risk, and project control practices. Direct construction and data center studies were treated as the primary evidence base, while studies from computing and other project management environments were used only where their treatment of critical path analysis, scheduling, optimization, or resource allocation provided transferable conceptual support.

Publicly available information published by Clune Construction was also examined to establish the practical context of data center scheduling. Clune's published material identifies early MEP coordination, procurement strategy, constructability planning, intentional sequencing, phased turnover, concurrent scheduling, and commissioning as relevant elements of its mission critical delivery approach.

The resulting themes were synthesized into a conceptual schedule control framework linking project planning, activity sequencing, Critical Path Analysis, continuous monitoring, risk analysis, resource prioritization, corrective action, and schedule performance.

2. Literature Review

2.1 Critical Path Analysis and Construction Scheduling

Critical Path Analysis provides a network-based approach to construction scheduling by establishing activity relationships, durations, and the sequence of activities that determines project completion. Menesi (2010) demonstrates the application of critical path analysis to construction scheduling, while Poliani (2019) discusses CPM as one of several approaches for construction planning and control.

The importance of the critical path extends beyond the initial preparation of a construction program. Hammad et al. (2020) show that changes in activity durations can result in changes to the critical path. This suggests that project schedulers need to periodically reassess the schedule rather than assume that the original critical path will remain unchanged throughout project execution.

2.2 Critical Path Analysis and Data Center Schedule Performance

Data center construction increases the importance of schedule coordination because multiple technical systems must be completed, integrated, tested, and commissioned before operational turnover. Clune describes its mission critical approach as incorporating early coordination, procurement, intentional sequencing, phased turnover, concurrent scheduling, QA/QC, and commissioning.

Clune has also documented situations in which delayed equipment threatened data center completion schedules. Its published experience describes the need to connect equipment lead times with the master schedule and to consider alternative equipment or installation approaches when procurement problems arise.

These conditions reinforce the relevance of CPA because procurement and installation activities may have dependencies that affect subsequent work. Identifying the activities with limited schedule flexibility can help the scheduler focus monitoring and coordination efforts where changes could have greater implications for project completion.

2.3 Schedule Risk and Changes to the Critical Path

Schedule risk occurs when uncertainty or changes affecting activities have the potential to alter project completion. Hammad et al. (2020) demonstrate the usefulness of sensitivity analysis for examining changes in the critical path. Menesi (2010) similarly highlights the importance of schedule relationships and time segments in construction scheduling.

In data center construction, schedule risks can include equipment delays, labor availability, coordination issues, design changes, site logistics, and commissioning requirements. Clune's published experience specifically identifies equipment lead times, supply chain disruption, vendor coordination, and material availability as issues requiring active schedule management.

For the project scheduler, the implication is that schedule risk should be linked to the network logic of the schedule. A risk affecting an activity on or near the critical path may require different monitoring and response than a risk affecting an activity with substantial schedule flexibility.

2.4 Resource Prioritization and Scheduling

Resources are closely connected to schedule performance because construction activities depend on appropriate labor, materials, equipment, subcontractors, and information. Agumalu (2021) identifies resource allocation and project planning as components of effective project management.

Research in scheduling optimization also demonstrates the relationship between critical paths, deadlines, dependencies, and resource related decisions (Doostali et al., 2021; Lal & Rama Krishna, 2018; Zhang et al., 2020). Although these studies address computing and workflow environments rather than construction, they provide supporting evidence for the broader principle that scheduling decisions can benefit from identifying activities that have strong relationships with completion constraints.

In a construction environment, however, prioritizing resources should not mean automatically assigning all available resources to critical activities. Resource decisions also need to consider productivity, safety, trade availability, workface constraints, procurement status, and the feasibility of accelerating particular activities.

2.5 Integration with Complementary Project Control Approaches

CPA can be integrated with other project control approaches rather than being treated as a standalone scheduling technique. Poliani (2019) discusses the relationship between CPM, Location Based Management Systems, and the Last Planner System, while

Ariza et al. (2025) examine the relationship between CCPM, BIM, and the Last Planner System in construction project performance.

Clune's own published material also identifies BIM, virtual construction, laser scanning, and other technology supported processes as part of its construction technology capabilities.

The implication is that CPA can provide the network logic for understanding scheduled driving activities, while complementary tools can provide additional information for coordination, visualization, production planning, and field control.

3. Findings

3.1 Critical Path Analysis as a Schedule Control Mechanism

The literature indicates that CPA provides more than an initial calculation of project duration. It provides a structured basis for identifying activities that influence completion and for determining where schedule flexibility exists (Menesi, 2010; Poliani, 2019).

The review further indicates that the critical path can change when activity durations or relationships change (Hammad et al., 2020). Therefore, effective schedule control requires periodic reassessment of the schedule.

From a project scheduler perspective, the process can be represented as:

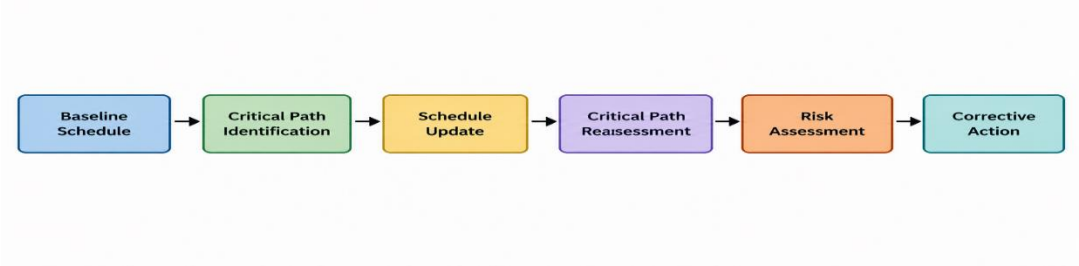

Figure 1. Continuous Critical Path Schedule Control Process

Source: Developed by the author.

This creates a continuous control cycle rather than a one-time scheduling exercise.

3.2 Factors Influencing Data Center Schedule Performance

Five major factors were identified from the reviewed literature and Clune Construction's publicly documented experience:

1. Activity duration changes: Changes in planned durations can alter the critical path (Hammad et al., 2020).

2. Procurement and equipment availability: Equipment lead times and material delays can affect planned construction activities.

3. MEP and trade coordination: Data center projects require close coordination of specialized systems and installation activities.

4. Resource availability: Labor, materials, equipment, and subcontractor availability influence the ability to execute planned activities (Agumalu, 2021).

5. Testing, commissioning, and turnover requirements: Completion of technical systems and phased turnover create additional schedule relationships in mission critical construction.

3.3 Critical Path Identification and Delay Management

The findings indicate that critical path identification can help the scheduler distinguish between activities that have greater potential influence on project completion and activities with greater schedule flexibility.

When an activity on the critical path experiences a delay, the scheduler can examine its successors, available float, and potential effects on project milestones. Hammad et al. (2020) provide support for reassessing critical path changes rather than assuming that the original critical path remains constant.

In the Clune context, this approach is particularly relevant to procurement and equipment related risks because Clune has documented the need to monitor vendor schedules, lead times, equipment availability, and alternative solutions to protect project schedules.

3.4 Resource Prioritization and Corrective Action

The findings suggest that critical path information can support resource prioritization by showing where delays may have greater implications for completion. However, resource decisions must remain subject to practical project constraints.

Corrective actions may include resequencing activities, adjusting trade resource levels, coordinating alternative work fronts, addressing procurement issues, or modifying planned work arrangements. Clune has documented examples of evaluating crew size, working hours, alternative equipment, and procurement strategies when responding to schedule pressures.

3.5 Proposed Critical Path Schedule Control Framework

Based on the literature and practical context, the following framework is proposed:

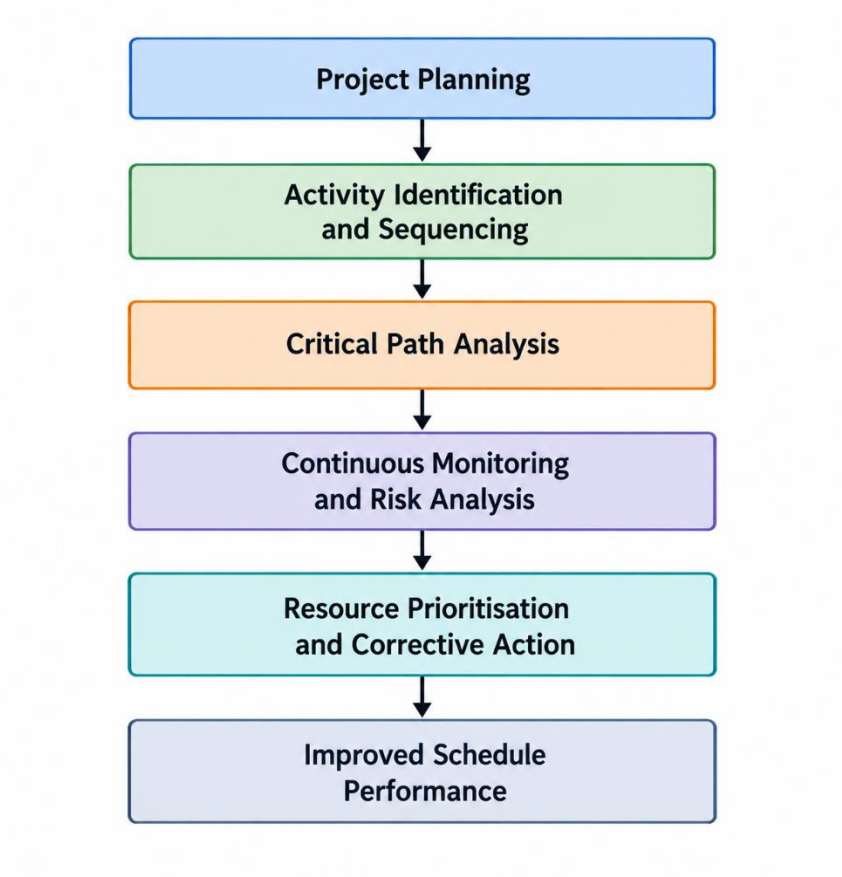

Figure 2. Proposed Critical Path Schedule Control Framework
Source: Developed by the author.

The framework positions CPA at the center of the scheduling process while recognizing that its effectiveness depends on continuous monitoring, risk assessment, resource decisions, and corrective action.

4. Discussion

The findings indicate that CPA can be particularly useful to project schedulers when it is treated as a dynamic schedule control process rather than simply as a scheduling calculation. The initial critical path establishes the activities that control planned completion, but subsequent schedule updates are required because changes in durations, dependencies, resources, and external conditions can alter the critical path (Hammad et al., 2020).

For data center construction, the relationship between scheduling and procurement is especially important. Clune's published experience demonstrates that equipment lead times and supply chain issues can directly affect project schedules, requiring early planning, vendor monitoring, alternative solutions, and coordination with the master schedule.

This suggests an important role for the project scheduler. The scheduler should not only record whether an activity is ahead or behind its planned date but should examine what the change means for the overall network. An isolated delay may have limited effect if sufficient float exists, whereas a delay to a critical or near critical activity may require immediate intervention.

The findings also support the integration of CPA with other project control practices. BIM, Last Planner System, location-based approaches, and other digital technologies can provide complementary information, while CPA provides a network based view of relationships and project completion (Poliani, 2019; Ariza et al., 2025). Clune's documented use of BIM and virtual construction technologies further demonstrates the relevance of technology supported coordination in its construction environment.

The practical implication is that schedule performance should be managed through a continuous cycle:

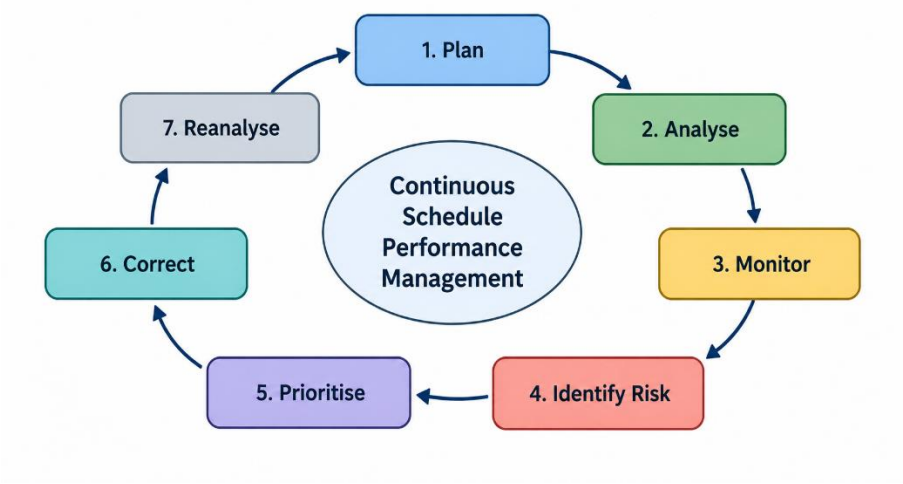

Figure 3. Continuous Schedule Performance Management Cycle
Source: Developed by the author.

This cycle is more appropriate to complex data center construction than treating the baseline schedule as a static document.

5. Answers to the Research Questions

Research Question 1: How can Critical Path Analysis be applied to data center construction scheduling?
CPA can be applied by identifying project activities, establishing their logical relationships, assigning durations, calculating schedule flexibility, and identifying sequence controlling project completion. The schedule should then be updated, and the critical path reassessed as project conditions change (Menesi, 2010; Hammad et al., 2020).

Research Question 2: What factors influence schedule performance in data center construction?
The principal factors identified are activity duration changes, procurement and equipment lead times, resource availability, MEP and trade coordination, project complexity, and testing and commissioning requirements. These factors are particularly relevant to data center construction because of the specialized systems and aggressive delivery requirements documented in Clune's mission critical practice.

Research Question 3: How can critical path identification support schedule monitoring and delay management?
Critical path identification enables the scheduler to focus attention on activities with limited schedule flexibility and to assess how changes may affect project completion. Sensitivity analysis and periodic schedule updates can be used to identify changes in the critical path (Hammad et al., 2020).

Research Question 4: How can critical path information support resource prioritization and corrective action?
Critical path information can indicate where resource intervention may have greater schedule significance. Resource decisions can include adjusting trade resources, addressing procurement constraints, resequencing work, or developing alternative execution strategies, subject to safety, productivity, and practical project constraints (Agumalu, 2021; Doostali et al., 2021).

Research Question 5: How can Critical Path Analysis be integrated into a practical schedule control framework?
CPA can be integrated into a continuous process consisting of project planning, activity identification and sequencing, critical path analysis, continuous monitoring and risk analysis, resource prioritization, corrective action, and schedule reanalysis. Complementary approaches such as BIM, LPS, and other project control technologies can provide additional coordination and field information (Poliani, 2019; Ariza et al., 2025).

6. Conclusion

This article examined the application of Critical Path Analysis for improving schedule performance in data center construction from a project scheduling perspective, using Clune Construction as the practical organizational context.

The review demonstrates that CPA provides a structured method for identifying schedule driving activities, understanding activity dependencies, determining schedule flexibility, and assessing the potential effects of delays. However, its effectiveness depends on continuous schedule monitoring because changes in activity durations, procurement, resources, coordination, and execution conditions can alter the critical path.

The article therefore proposes that project schedulers use CPA as a continuous schedule control mechanism rather than as a onetime planning calculation. The proposed framework connects project planning, activity identification and sequencing, Critical Path Analysis, continuous monitoring and risk analysis, resource prioritization and corrective action, and improved schedule performance.

The principal contribution of the article is its application-oriented perspective, which places the scheduler at the center of the relationship between the project schedule and project execution. Rather than simply reporting schedule variance, the scheduler can use critical path information to identify emerging schedule threats, communicate their potential effects, support resource and procurement decisions, and facilitate corrective action.

The article is conceptual and literature based; therefore, its conclusions should not be interpreted as measured evidence of Clune Construction's actual schedule performance. Further research could strengthen the framework through analysis of an actual data center project schedule, including baseline and update schedules, critical path changes, procurement delays, resource data, and achieved versus planned milestones.

7. Recommendations

- Use CPA from the planning stage. Data center project schedules should establish activity relationships and the initial critical path before major execution begins.
- Reassess the critical path regularly. Schedule updates should be analyzed to determine whether changes in durations or dependencies have created a new critical or near critical sequence.
- Connect procurement with schedule analysis. Long lead equipment and material procurement should be linked to the master schedule so that potential delivery problems can be identified before they affect critical activities. This is consistent with Clune's documented approach to data center procurement and schedule management.
- Monitor critical and near critical activities. Project schedulers should monitor not only activities currently on the critical path but also activities with limited remaining float.
- Link schedule risk to corrective action. Identified risks should be assessed according to their potential effect on critical activities, milestones, and project completion.
- Use critical path information to support resource decisions. Resource adjustments should consider the critical path alongside safety, productivity, workface availability, procurement status, and technical constraints.

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