CHAPTER 47

Critical Chain Project Management (CCPM) in EPC Projects

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ABSTRACT

Engineering, Procurement, and Construction (EPC) projects face constraints in time, cost, and resources, making efficient management essential. This study examines Critical Chain Project Management (CCPM) adoption in EPC projects, focusing on resource optimization, buffer management, and risk mitigation. A structured survey of industry professionals was analyzed using statistical tools to assess CCPM's impact on project duration, cost efficiency, and stakeholder satisfaction. Findings indicate CCPM reduces multitasking, enhances resource utilization, and mitigates schedule overruns. However, challenges like organizational resistance and integration issues hinder widespread adoption. Despite its potential, the success of CCPM relies on organizational buy-in, training, and technological integration.

Keywords: Critical chain project management; EPC projects; Resource optimization; Buffer management; Risk mitigation.

1.0 Introduction

Critical Chain Project Management (CCPM) optimizes resource allocation, buffer management, and risk mitigation, enhancing efficiency in Engineering, Procurement, and Construction (EPC) projects. Traditional methods like CPM and PERT struggle with uncertainties, leading to delays and cost overruns. CCPM addresses these issues by strategically placing buffers to absorb variability and protect the critical chain, ensuring smooth project execution and on-time completion.

1.1 Research objectives

- To examine the integration of CCPM in EPC projects.
- To explore the impact of CCPM on project time, safety, and quality.
- To study CCPM's role in minimizing risks and optimizing resource utilization

1.2 Research problem

Despite its advantages, the adoption of CCPM in the EPC sector remains limited.

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DOI: 10.17492/JPI/NICMAR/2507047 *ISBN: 978-93-49790-54-4*

Many organizations continue to rely on conventional project management approaches, often due to resistance to change, lack of awareness, or integration challenges with existing frameworks. There is limited research on the impact of CCPM on key performance parameters such as project cost, duration, safety, and quality in EPC projects. Addressing these challenges requires a deeper understanding of CCPM's applicability, barriers to adoption, and potential strategies for integration into existing EPC project frameworks.

2.0 Literature Review

Critical Chain Project Management: Guofeng *et al.* (2014) introduced CCDSM to reduce rework risks, improving on-time completion but requiring further research on large- scale modeling. Roy *et al.* (2015) highlighted CCPM's impact on project performance, though its relationship with lean concepts needs clarity. Livia *et al.* (2023) demonstrated CCPM's benefits in construction but noted implementation challenges. Mohammad *et al.* (2020) compared CCPM with traditional methods, proving its superiority but identifying software limitations and cultural adoption gaps. Taynara *et al.* (2021) showed CCPM outperforms PERT/CPM but requires further study on human behavior influences. Amancharla *et al.* (2023) emphasized CCPM's effectiveness but noted limited adoption in construction.

Buffer Sizing: Shakib *et al.* (2020) introduced BSCA, reducing project duration by 15%, but real-time buffer management research is needed. Jun-Long *et al.* (2022) proposed brittle risk entropy for shortening project completion but highlighted a lack of system-perspective methods. Mona *et al.* (2017) emphasized CCPM's role in India but noted limited implementation. Geekie *et al.* (2008) proposed a mixed buffer-sizing approach requiring refinement. Bingling *et al.* (2020) introduced network decomposition for better scheduling but emphasized further testing.

Extension of Time (EoT) Claims: Eranga *et al.* (2023) emphasized excusability and criticality, identifying window analysis as reliable but lacking an integrated framework. Khaled *et al.* (2014) highlighted challenges in proving delays, calling for AI-based assessments. Haroon *et al.* (2017) identified 29 influencing factors but emphasized the need for deeper managerial delay analysis. Reuben *et al.* (2021) stressed contract management in multi-stakeholder projects, noting research gaps in developing countries. Norazian *et al.* (2013) analyzed disputed EoT claims in Malaysia, highlighting concurrent delays. Ayush *et al.* (2017) advocated adherence to contract protocols in Indian construction.

EPC Contracts: Hansen *et al.* (2015) identified 34 unique EPC characteristics, emphasizing knowledge management. Kamyar *et al.* (2019) highlighted engineering design and procurement as crucial factors. Sonawane *et al.* (2017) compared PPP and EPC contracts, emphasizing risk management. Mittal *et al.* (2020) addressed delay mitigation in EPC solar projects, advocating stakeholder coordination. Sanjay *et al.* (2019) examined price volatility, recommending revised escalation clauses.

DOI: 10.17492/JPI/NICMAR/2507047 ISBN: 978-93-49790-54-4

3.0 Methodology

3.1 Research approach

The research employs a quantitative approach, utilizing a structured questionnaire to gather data from industry professionals involved in EPC projects. This approach allows for the collection of insights regarding familiarity with CCPM, resource allocation, EoT claims, buffer management, risk management, safety and quality, challenges.

3.2 Data collection method

The primary data collection method is a questionnaire survey, administered to a target group of professionals working in fields such as construction, energy, infrastructure, manufacturing, and other sectors. The survey is structured into multiple sections like 1. General information 2. Resource allocation and prioritization 3. EoT Claims 4. Buffer management 5. Risk management 6. Project execution, safety and quality 7. Technology and software 8. CCPM challenges and future outlook. Upon completion of data collection, responses will be analyzed quantitatively.

4.0 Data analysis and Findings

4.1 Adoption level of CCPM

The adoption of CCPM in project-driven industries appears to be limited. Based on the survey results, only 6% of respondents primarily use CCPM, while the majority (66%) rely on the CPM, followed by Traditional Waterfall and Agile/Lean methodologies.

4.2 Compatibility of CCPM with existing EPC project frameworks

A majority (80%) of respondents consider CCPM to be moderately compatible with existing EPC project frameworks, indicating that while CCPM has potential, it is not a seamless fit. Only a small percentage (9%) believe it is highly compatible. To improve its integration, organizations should focus on training project teams to build awareness and competence in CCPM principles, enhance software tools to support CCPM methodologies, gradually integrate CCPM into current frameworks through pilot projects before full-scale implementation.

4.3 Impact of CCPM on reducing resource wastage

36% observed a significant reduction in resource wastage,33% noticed some reduction but not significantly, 31% saw no noticeable difference. While CCPM helps reduce resource wastage for most, a substantial portion (31%) sees no improvement, suggesting the need for better implementation strategies.

DOI: 10.17492/JPI/NICMAR/2507047 *ISBN: 978-93-49790-54-4*

Recommendations:

- Prioritize Key Resource Allocation Factors: Ensure that project timeline, resource criticality, and availability are systematically incorporated into planning.
- Implement buffer management strategies to mitigate frequent resource shortages.
- Optimize Waste Reduction Strategies: better tracking and analysis methods should be introduced to enhance resource utilization.
- Training and Awareness

4.4 Impact of CCPM on resolving EOT claims

- Primary Causes: Late approvals (34%), design delays (24%), supply chain disruptions (24%), and force majeure events.
- CCPM Benefits: Reduces delays (31%), improves resource utilization (24%), and enhances critical path identification (23%).

Figure 1: Benefit of CCPM in EOT

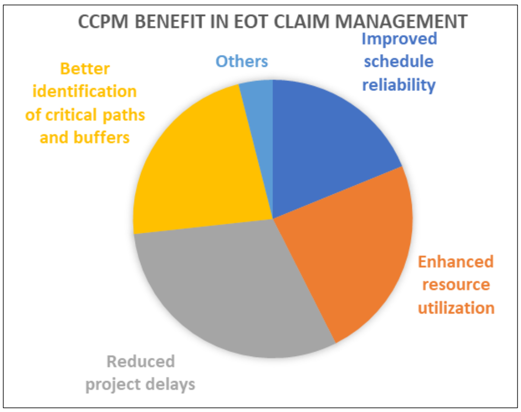
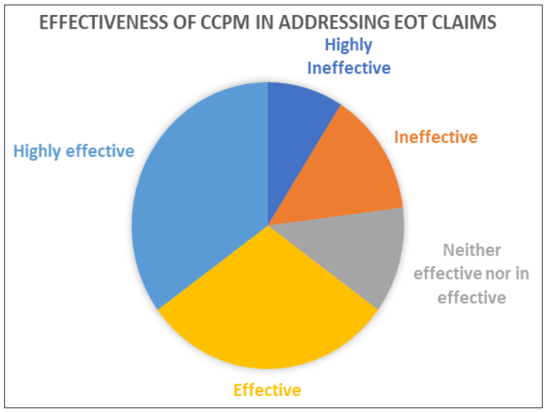


Figure 2: Effectiveness of CCPM in EoT Management



4.5 Buffer management

While 42.8% find it somewhat effective in handling uncertainties, 31.4% consider it ineffective, likely due to low familiarity, improper implementation, or unrealistic buffer sizing. Improving data collection, advanced forecasting, and targeted training programs can enhance buffer utilization and stakeholder confidence.

4.6 Risk management & uncertainty

CCPM is seen as effective in risk identification by 44% of respondents, though 31% find it ineffective, indicating inconsistencies in its application. While 48% believe CCPM helps manage schedule risks, 30% disagree, highlighting implementation challenges. Additionally, 64% feel CCPM positively impacts unforeseen challenges, but 33% see no change.

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Figure 3: Effectiveness of Buffer Management in Handling Uncertainties

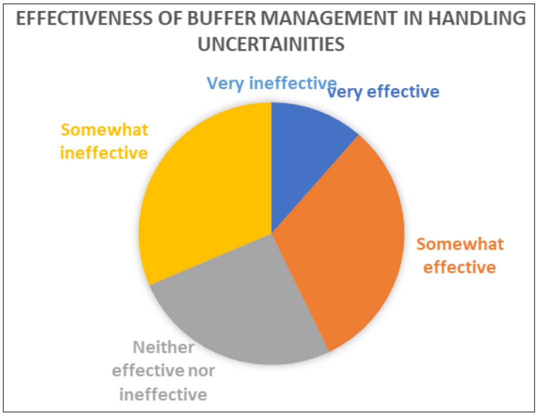
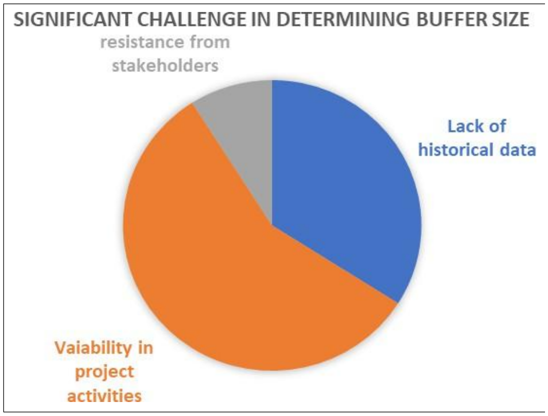


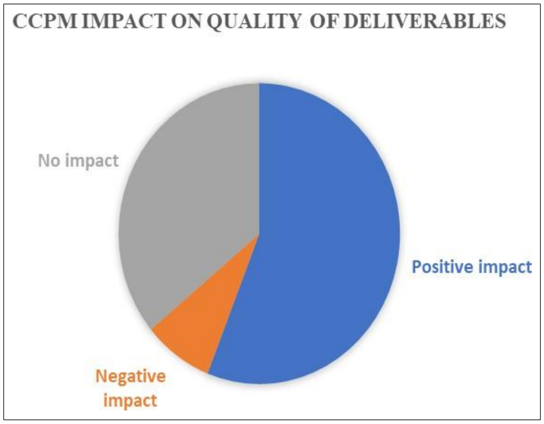
Figure 4: Challenges in Determining Buffer

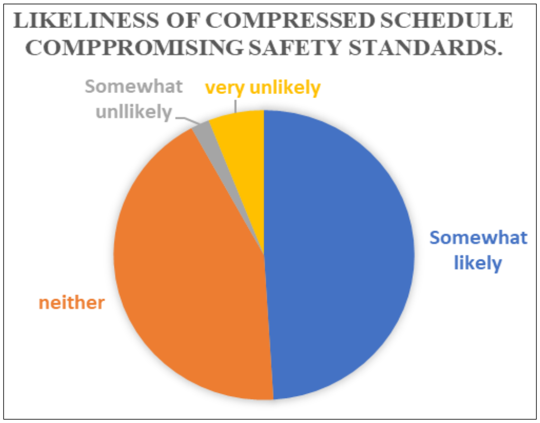


4.7 Other findings

4.7.1 CCPM's impact on quality and safety

Figure 5: CCPM's Impact on Quality and Safety





4.7.2 CCPM future outlook

The team is found to be generally open to CCPM, but the majority are still in early stages of acceptance. There is a further requirement of training, change management efforts and demonstrating clear benefits to increase strong adoption. The majority are unsure whether CCPM will become a standard methodology in their respective sectors.

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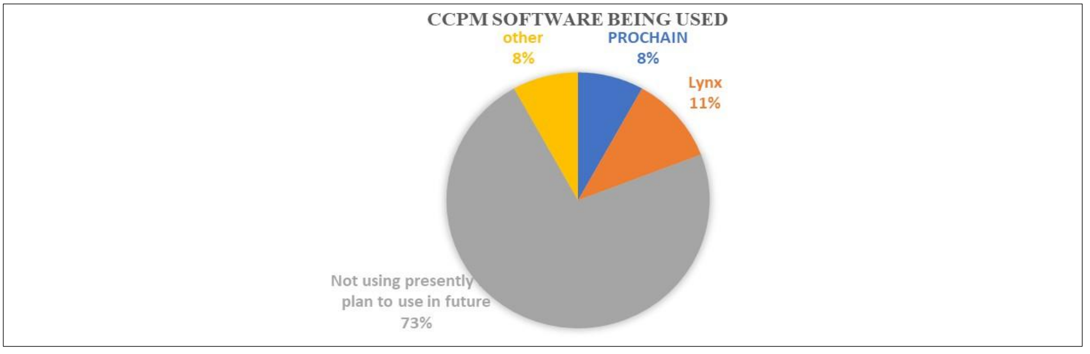
5.0 Conclusion

5.1 Key findings

- *Limited adoption and awareness:* Only 6% of industry professionals currently use CCPM. 66% of respondents were somewhat familiar with CCPM, but only 17% were highly familiar.
- *Effectiveness in resource allocation and project execution:* 50% of respondents found CCPM effective in managing resources, but 31% saw no noticeable reduction in resource wastage. CCPM significantly reduces project delays (31%) and improves critical path identification (23%).
- *Challenges in buffer management and risk mitigation:* 74% of respondents had little or no familiarity with buffer management, leading to ineffective implementation. Variability in project activities and a lack of historical data were key obstacles in determining buffer sizes.
- *Impact on safety and quality:* 49% of respondents believed compressed schedules under CCPM might pose safety risks, highlighting the need for better safety integration. While most respondents agreed that CCPM improves quality, they emphasized the importance of regular audits and enhanced quality checks.
- *Technology and software adoption:* Only 27% of respondents used CCPM software, with Lynx and ProChain being the most common tools.

Figure 6: CCPM Software Used



5.2 Limitations of the study

- *Limited industry representation:* A larger sample size with more diverse participants would enhance the reliability of findings.
- *Dependence on survey-based responses:* which may be influenced by personal biases, knowledge gaps, or subjective experiences.
- *Technological constraints:* The study did not extensively analyze the role of advanced digital tools, such as AI-driven CCPM solutions.

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5.3 Recommendations

- *Enhance awareness and training:* Organizations should invest in workshops, training programs, and pilot projects to increase CCPM adoption.
- *Improve integration with EPC frameworks:* Customization of CCPM principles to align with existing workflows can facilitate smoother adoption. A hybrid approach combining CPM and CCPM can improve compatibility.
- *Optimize resource and buffer management:* Advanced forecasting techniques and historical data analysis should be employed to determine optimal buffer sizes.
- *Encourage technology adoption:* More organizations should explore CCPM-compatible software for improved tracking and forecasting.

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DOI: 10.17492/JPI/NICMAR/2507047 *ISBN: 978-93-49790-54-4*

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DOI: 10.17492/JPI/NICMAR/2507047 *ISBN: 978-93-49790-54-4*