Evaluation of the CCPM Method and Its Software Applications

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ABSTRACT

Project time planning involves dividing the project into phases and setting deadlines for each task and for the overall project. In project management, the CCM method can be used to develop a project plan and, during project execution, to manage risks in the project network by monitoring and controlling the Feeding Buffers (FB) and Project Buffer (PB). In this study, project planning and the creation of dynamic schedules using the Critical Chain Method (CCM), along with their graphical representation, were conducted using MS Project and the add-in tools cc-Pulse (Spherical Angle, Inc.) and CCPM+ (Advanced Projects, Inc.). These software tools facilitated the visualization of the project network, the allocation of resources, and the monitoring of buffer consumption, providing managers with real-time insights into project performance. The research results demonstrate that implementing the CCM method significantly improves project efficiency. Specifically, project planning with CCM reduced the total project duration by approximately 25% compared to traditional Critical Path Method (CPM) planning. This reduction is achieved through the focus on the critical chain, effective buffer management, and optimized resource use. CCM provides a structured approach that helps projects meet deadlines while minimizing risks and resource conflicts.

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1. Introduction

Planning is the primary phase of any management process, and this is equally true for project management. Construction project management involves the systematic planning, coordination, and supervision of all phases of a construction project, from initial concept through final completion. Its primary objective is to ensure that the project is completed on schedule, within the approved budget, and in compliance with defined quality standards. The most well-known project planning methods are the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). Both methods were developed in the 1950s, yet they still form the foundation of modern project management research. Since 1997, a new planning technique known as the Critical Chain Method (CCM) has been used, becoming increasingly popular and competitive with the traditional Critical Path Method (CPM).

The Critical Chain Method (CCM) is a highly effective project management approach that has demonstrated significant advantages in planning and executing projects, particularly in complex and resource-constrained environments. When developing a project schedule, CCM considers not only the logical interdependencies between activities but also the availability of limited resources and the use of buffers to manage uncertainty. By identifying the critical chain, the sequence of dependent tasks that directly determines the project's duration, CCM focuses attention on the most impactful activities, ensuring that delays in these tasks are minimized and managed effectively.

In addition to scheduling, CCM emphasizes strategic buffer management, including the use of project buffers, feeding buffers, and resource buffers, to absorb variations in task durations and prevent delays from propagating throughout the project. Resource leveling strategies are applied to avoid over-allocation and conflicts, ensuring that critical resources are available when needed. By concentrating on these critical tasks and buffers, CCM reduces project duration, mitigates the effects of uncertainty and variability, and enhances schedule reliability. This method also promotes a more predictable and efficient project execution process, providing managers with actionable insights for decision-making, early warning of potential delays, and a structured approach to maintaining project objectives. Overall, CCM integrates scheduling, resource management, and risk control into a cohesive framework, making it a powerful tool for improving project performance and achieving on-time project completion.

2. Literature review

The Critical Path Method (CPM) was developed in the 1950s and quickly became the most widely used method for project management. The CPM calculation begins with arranging activities into a logical network and establishing relationships among them. The durations of individual activities are then determined, and forward and backward calculations are performed to identify the critical path in the project network schedule. The critical path consists of activities that have no time float and are therefore called critical activities. The time required to complete the project is equal to the sum of the durations of the activities on the critical path. Consequently, any delay in the execution of activities on the critical path leads to a delay in the completion of the entire project. Activities that are not on the critical path are referred to as non-critical activities and have a certain amount of time float. A delay in a non-critical activity up to the value of its total float will not affect the planned project completion time; however, a non-critical activity may become critical, resulting in multiple critical paths and increasing the likelihood that the project will not be completed on schedule (Goldratt, 1997), (Lechler et al., 2005).

Critical Chain Project Management (CCPM) is a project management methodology focused on optimizing the use of critical resources and prioritizing task dependencies in order to complete projects as efficiently as possible. In the CCM method, Goldratt applies the Theory of Constraint (TOC) to the planning and execution of projects, adhering to the principle that work on activities changes over time. The purpose of TOC is to increase the limitation, which represents an obstacle in the process of achieving the goal, that is, it is necessary to remove the obstacles in order to solve the limitation (Goldratt, 1997). Management using TOC is based on the fact that every complex system at any given moment usually has only one constraint that prevents it from achieving its goal. The main goal of every project is to satisfy the needs of all project participants, i.e. to complete the project within the planned budget and time. After defining the goal and constraints, in order to achieve the best results and system success, TOC suggests using the steps shown in Fig. 1 (Goldratt&Cox, 2004)

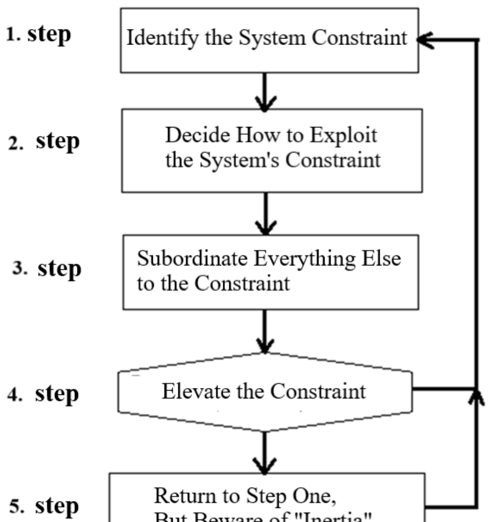

Figure 1. TOC steps (Goldratt&Cox, 2004)

Goldratt's idea is to discover the 'bottlenecks' of the system (i.e Drums) and in order to protect the system from uneven fluctuations in the process, it is necessary to place buffers in front of the 'bottlenecks', so that the system's constraints never lack input units. The CCM method protects the project plan from disruptions using different types of time buffers, placed at strategic locations. These buffers absorb the negative impact of extended activity durations on the overall project duration, allowing the project to be completed on time. A buffer is not the same as a time reserve in the Critical Path Method (CPM), which exists but is not visible in the network plan. In the CCM method, time buffers, i.e., buffers, are visible in the network plan because they are shown as activities that have duration but no resources (Lechler et al., 2005), (Vanhoucke, 2012)

The CCM method uses three types of buffers (Leach, 2004):

- Project Buffer - PB,
- Feeding Buffer - FB,
- Resource Buffer - RB.

The arrangement of buffers in the network plan of the project is shown in Figure 2.

The third type of buffer used in the CCM method is called a protector, or resource buffer. In the network diagram, it is represented as a virtual activity placed immediately before a critical activity in order to ensure that the resources assigned to that critical activity are not delayed, as shown in Figure 2. Such resources are referred to as critical resources and must not work on multiple activities simultaneously. A resource buffer does not consume time or resources; it is added as an alarm or warning to notify resources that they need to be ready to start work on critical activities, i.e., that they have X days before beginning the next activity. In this way, the critical chain is protected from the unavailability of required resources, and it is ensured that critical activities can start earlier than planned, enabling the project to be completed on time.

To achieve success in any business, especially in construction, effective project management is crucial. Project management involves a set of activities that include planning, executing, controlling and completing projects. To simplify this complex process, project management computer programs are used. Several standalone computer programs and add-in solutions have been developed for planning and managing projects using the CCM method, all of which are listed in Table 1.

Table 1. Software for Planning and Managing Projects Using the CCM Method (Popović-Miletić, 2022)

Software Name	Company Owner	Year of Creation	Compatibility with MS Project
Agile-CC for Adept Tracker	WangTuo Software	2008.	Standalone software, allows import/export of data with MS Project
Aurora-CCPM	Stottler Henke Associates, Inc.	2005.	Standalone software, allows import/export of data with MS Project
Being Management 3	Being Co. Ltd.	2007.	Standalone software, allows import/export of data with MS Project
LYNX CCPM LYNX TameFlow	A-dato B.V.	2012	Standalone software, allows import/export of data with MS Project
Exepron	Dux Global, Inc., Exepron	2010.	Standalone software, allows import/export of data with MS Project using the API Analyzer
Concerto	Realization Technologies, Inc.	1998.	The newer version is standalone software, while the older version has Concerto's Planning Module integrated with MS Project.
cc-Pulse/cc-MPulse	Spherical Angle	2003.	Add-in software for upgrading MS Project (only for MS Project 2000 – 2007)
CCPM+	Advanced Projects, Inc	2002.	Add-in software for upgrading MS Project (from MS Project 2002 to 2010)
ProChain	ProChain Solutions, Inc.	1997.	Add-in software for upgrading MS Project
Sciforma (from 2011) PSNext (from 2004 to 2011)	Sciforma Corporation	2004.	Standalone software, allows import/export of data with MS Project

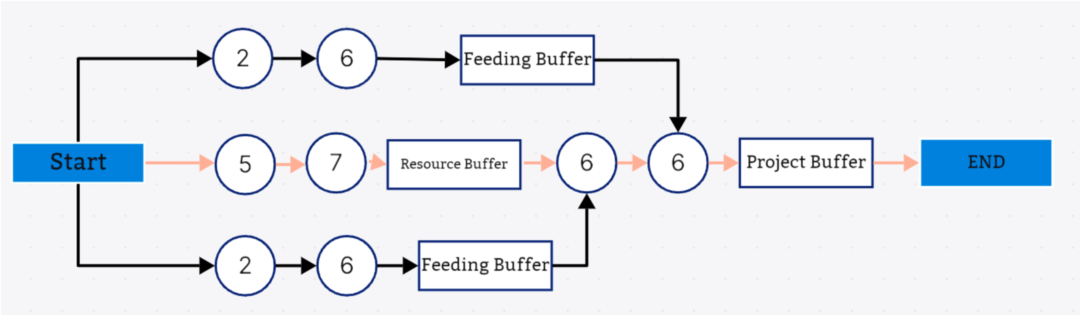

Figure 2. View of the buffers in the CCM network diagram

3. Research materials and methods

Project management software enables businesses and organizations to achieve their goals more efficiently and effectively. It assists project managers and stakeholders throughout the project management life cycle, particularly during planning, execution, and monitoring phases.

In this work, for project planning and creating dynamic plans using the Critical Chain Method (CCM) and their graphical representation, the software MS Project and add-in software cc-Pulse (Spherical Angle, Inc.) and CCPM+ (Advanced Projects, Inc.) were used.

CC-Pulse and CC-(M)Pulse are add-in programs for Microsoft Project that implement the concepts of Critical Chain Project Management. CC-Pulse facilitates easy project management in a single-project environment, while CC-(M)Pulse is designed for a multi-project environment. These programs can be used with older versions of MS Project, 2000, 2003, and 2007, but newer versions of MS Project do not support these programs (cc-Pulse).

CCPM+ is an add-in program for Microsoft Project developed by Advanced Projects, Inc. The program enables automatic identification of critical chains and supply chains, calculation of Project Buffers (PB) and Feeding Buffers (FB), determination of activities that are resource priorities, and tracking of the longest chain. The program offers all the basic functions for easy project management in both single-project and multi-project environments. The secure duration of activities is entered manually, while the reduced duration can be calculated using the software (50% of the secure duration) or the calculation method can be manually specified. However, despite significant interest in integrating risk by applying the CCM method, most software only includes the risk of individual activities in the buffers using the difference between secure and reduced duration. In contrast, the CCPM+ program offers three options for buffer calculation: by entering the desired percentage, using the RSEM method, or combining the percentage and RSEM method. Additionally, the CCPM+ program allows the Feeding Buffer (FB) to be excluded (set to zero) and does not permit the merging of activities or simultaneous work on multiple activities (i.e., multitasking) (Zhang, 2016).

The Root Square Error Method (RSEM) calculates PB and FB using the following formula (Newbold, 1998):

$$PB = 2 * \sqrt{\sum_1^n \sigma^2} = 2 * \sqrt{\sum_1^n \left(\frac{t_{0,9} - t_{0,5}}{2}\right)^2} \quad (1)$$

Where:

$t_{0,9}$ is the safe (pessimistic) activity duration, with a 90% probability that the activity will be completed within the planned time,

$t_{0,5}$ is the reduced (average) activity duration, with a 50% probability that the activity will be completed within the planned time,

$\sigma = (t_{0,9} - t_{0,5})/2$ is standard deviations of activities.

Buffer sizing in the Critical Chain Method is done using the C&PM method. The activity durations $t_{0.5}$ are 50% of the deterministic durations $t_{0.9}$ used in the CPM method (Table 2). For project planning using the CCM method, the shortened activity duration $t_{0,5}$, is used, and the subtracted time $\Delta t_i = (t_{i,0.9} - t_{0.5})$ is used to calculate the time buffers using the C&PM method (Goldratt,1997).

The Cut and Paste Method (C&PM) calculates PB and FB using the following formula (Zhang & Liu, 2025):

$$B = \sum_1^n \left(\frac{t_{0,9} - t_{0,5}}{2}\right) \qquad (2)$$

The Project Buffer (PB), safeguards the planned project completion date from delays that may occur due to overruns in the durations of activities on the critical chain. It is placed at the end of the project, after the last activity on the critical chain, as shown in Figure 2. The total project duration equals the sum of the critical chain duration and the project buffer duration (She, et al., 2021). If some activities on the critical chain are not completed on time, the project completion date remains unchanged because the project buffer absorbs the overruns of activities, thereby protecting the project from delays.

The Feeding Buffer (FB), also called a supply or non-critical buffer, is placed at the end of each non-critical chain that feeds into the critical chain, providing the critical chain with protection against delays. In the network diagram, it is represented as an activity with a duration but no assigned resources. The purpose of this buffer is to protect the critical chain and the project from uncertainty, while allowing critical activities to start earlier if possible. If some activities in the feeding chain (non-critical chain) are not completed on time, the completion date of that chain will remain unchanged because the feeding buffer absorbs the activity overruns, thereby protecting the critical chain from delays. The duration of the feeding chain equals the sum of the durations of its activities plus the feeding buffer. If the feeding chain takes longer than planned, it could delay the start of the critical activity into which the chain feeds. This, in turn, could prevent the critical chain from finishing on time, potentially causing a project delay (Kerzner, 2003).

Buffer management in the Critical Chain Method is used to monitor project progress, tracking buffer consumption and replenishment to ensure the project is completed on time. The focus is on the project's completion rather than individual activities. The project buffer is consumed as delays accumulate in the critical chain. Actions in buffer management depend on the extent to which the project buffer has been used, known as buffer penetration. This measure provides early warning of potential project issues, indicating the likelihood of on-time completion and guiding necessary corrective actions to keep the project on schedule. To facilitate buffer management, the project buffer is divided into three zones, as shown in Figure 3.

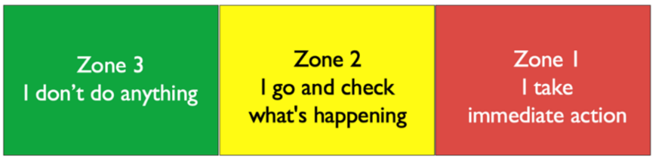

Figure 3. Buffer management zones, i.e., project time buffers (Goldratt&Cox, 2004)

If 33% of the project buffer is consumed (the first zone), no action is required, as there is a high probability that the project will be completed on time. When the project buffer is consumed between 33% and 66% (the second zone), no immediate action is required, but managers should consider what measures to take if delays in critical chain activities exceed expected values and push buffer penetration into the third (red) zone. The situation becomes much riskier when more than 66% of the project buffer is consumed (the third zone). Managers must then act quickly and adjust the remaining project plan to restore the project's protection level and prevent delays. Protective measures may include replanning the project to allow some activities to be performed in parallel rather than sequentially (accepting the associated risks), adding resources, changing priorities, or other project-specific options (Goldratt, 1997), (Lechler et al., 2005).

It is also possible that no protective actions are needed even when the buffers are in the red zone if the project is near completion, as the full use of the project buffer is already planned.

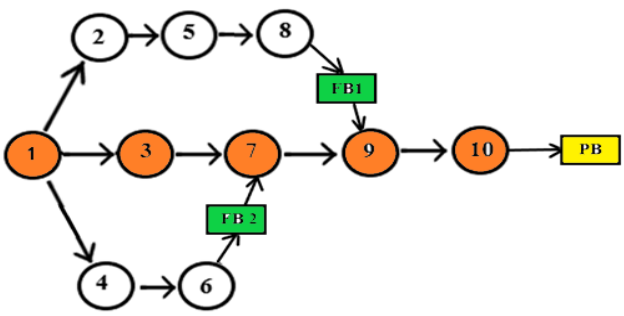

Figure 4. Network plan according to CCM methods

Table 2 presents the detailed input data used for developing project plans with both the Critical Chain Method (CCM) and the Critical Path Method (CPM). This data includes the durations of individual activities, their dependencies, and resource requirements, providing the foundation for accurate scheduling and buffer calculations. The corresponding network plan, illustrated in Figure 4, visually represents the sequence of tasks, critical paths, and interdependencies between activities.

Table 2. Activity Durations and Dependencies

Observed Activity	Predecessor Activity	Successor Activity	CPM Duration *t0.9* (days)	CCM 50% duration *t0.5* (days)	*Δti =(t0.9–t0.5)* (days)
1		2,3,4	10	5	5
2	1	5	8	4	4
3	1	7	18	9	9
4	1	6	6	3	3
5	2	8	8	4	4
6	4	7	10	5	5
7	3,6	9	20	10	10
8	5	9	6	3	3
9	7,8	10	18	9	9
10	9		10	5	5

4. Research results

Comparing the network plans for CCM and CPM allows for a detailed analysis of scheduling differences, identification of potential bottlenecks, and assessment of how buffer placement affects project duration and risk management. This comparison provides crucial insights into how each method manages task sequencing, resource allocation, and overall project timelines, highlighting the strengths and limitations of both approaches.

The duration of the project using the traditional CPM method is 76 days. The obtained results of buffers PB and FB, as well as the project duration using the CCM method, are shown in table 3.

Table 3. Buffer calculation and project duration by CCM - C&PM

Chain in network	Type of chain	Duration of chain (days)	Buffer size (days)	Total chain duration (days)	Project Duration (days)
2--5-8 –FB1	non critical	11.0	5.5	15.5	
1-3-7-9-10-PB	critical	38.0	19.0	57.0	57.0
4-6- FB2	non critical	8.0	4.0	12.0	
		Bafer=0.5*∑Δti			

5. Discussion and conclusion

The Critical Chain Method (CCM) is a relatively recent approach in project planning and management that has gained significant recognition and acceptance in practice. It builds on traditional project scheduling techniques by explicitly considering resource constraints and uncertainty in task durations. Due to its focus on buffer management and efficient use of critical resources, CCM has been successfully applied across a wide range of industries and business sectors worldwide, helping organizations improve schedule reliability, reduce project durations, and increase the likelihood of on-time project completion.

In project management, the CCM method can serve as a foundation for developing a comprehensive project plan, providing a structured approach to scheduling and resource allocation. During project execution, CCM functions as a vital tool for managing and mitigating risks within the project network. This is achieved through the systematic monitoring and control of Feeding Buffers (FB) and Project Buffers (PB), which absorb uncertainties and delays in both critical and non-critical tasks. By focusing on buffer management, CCM helps ensure that critical activities are completed on time, resources are optimally utilized, and potential project delays are identified early, allowing project managers to take corrective actions to maintain the planned schedule.

The effectiveness of the Critical Chain Method (CCM) is evident in its ability to shorten project durations and optimize resource utilization, which in turn improves cost control. Research results have demonstrated that using CCM for project planning can reduce the total project duration by approximately 25% compared to traditional CPM planning, highlighting its efficiency and practical benefits in managing complex projects.

Despite its many proven advantages over traditional methods, the CCM method is less widely adopted in the construction industry, primarily because its implementation requires substantial effort, changes to existing processes, and thorough training of personnel within a company's operations.

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