CRITICAL CHAIN AND CRITICAL PATH, CAN THEY COEXIST?

EXECUTIVE SUMMARY

PURPOSE: This paper is a comparison and contrast of two project management planning and execution methodologies: critical path methodology (CPM) and the critical chain project management (CCPM). It shows what each offers for project performance and provides decision makers with a foundation to make informed choices on the employment of each.

THESIS: If properly designed, the CPM and CCPM methodologies can coexist in project-based organizations; however, CPM offers no execution methodology and should subordinate to CCPM during execution in order to achieve the highest probability of on time, on-scope, and on-budget project delivery.

APPROACH: We begin by examining today’s reality that most projects do not finish on time, on-scope, and on budget. We outline typical failures in planning and execution as well as some of the execution challenges and obstacles that organizations encounter. We then identify and define the characteristics of planning and execution that have proven most effective in negotiating these challenges.

ANALYSIS: We compared CPM and CCPM against the characteristics of a reliable planning and execution process. We then discuss where conflicts might arise when the two methodologies are used in concert. Comparison results:

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CONCLUSIONS: CCPM is a superior solution when graded against the characteristics of reliable planning and execution process. Where other external factors may make it impossible to fully disengage from the critical path method, we’ve outlined a case where CPM and CCPM can coexist. To provide optimal results and avoid conflicts during execution, this coexistence must be properly designed.
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DEFINITIONS

**CPM** is a scheduling method to identify the shortest time a project could be accomplished assuming resources are infinite\(^1\). The critical path method (CPM) is a project modeling technique developed in the late 1950s by Morgan R. Walker of DuPont and James E. Kelley, Jr. of Remington Rand. In project management, a critical path is the sequence of project network activities that add up to the longest overall duration.

**CCPM** is a method of planning and managing projects that put the main emphasis on the resources required to execute project tasks. It is process; a collection of methods including:

A Project Scheduling method with the following characteristics:
- Identification of the critical path considering resource availability
- Backward planning (from due date)
- Aggressive task estimates
- Explicit definition of schedule risk using buffers

A Project Execution method with the following characteristic:
- Preemptive management using buffer status to prioritize work (schedule risk status)

WHY DO PROJECTS FAIL TO DELIVER?

We cannot properly evaluate the performance of the two methods if we don’t first make a reasoned evaluation as to why we would bother looking at a different way of managing projects. In short, conventional project management does not work\(^2\). More education in project management principles is not a predictor of good project performance, nor is the number of project managers, or the presence – or absence – of conventional software programs. This is true in all industries, across company sizes, and around the world. Few projects realize their objectives in cost, performance, and scope. Let’s begin by understanding why projects fail to deliver.

FAILURES IN PLANNING

**Work is not properly identified (too much detail or not enough).** This is a major conflict in project environments. When not enough detail is planned:
- Key tasks can get missed
- Integration points are not properly linked and work is not available to meet up with other completed tasks
- Resource loads are underestimated

As a result, projects end up late or require herculean efforts to finish because the work was significantly understated.

\(^1\) Although many software packages allow the critical path to be resource loaded, the output is no longer the critical path; it is

\(^2\) The Standish Report has cited that over 90% of IT projects are unsuccessful. One does not have to look far to verify their findings in other environments as well.
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Most project managers err on the side of building complex networks with a lot of detail. With too much detail:

- Project plans can become task lists
- The plans are unmanageable
- Resource requirements are overstated
- Managers use ad hoc systems to manage key tasks they know are important

These also cause delays to projects and waste management time during execution.

The resources to do the work are not sufficiently identified. This can cause significant delays. When resource requirements are understated, it appears that there is capacity to start new projects when that is not the case. As a result the system becomes overloaded and projects are delayed.

The relationships between tasks and resources are improperly defined (the breakthrough of the CCPM method). Missing key links between tasks can cause delays in starting key integration points as they are waiting on work that should have been completed. This requires extra effort to get that work complete within the required time and can make projects late.

Critical resources are not identified. This can cause delays because the resources might be committed elsewhere and not available when required.

Schedule risk is not explicitly stated. If not stated, it can be missed and cause serious delays.

FAILURES IN EXECUTION

Schedule risk is not effectively identified. If risk is not clearly identified and its magnitude understood, it can be mismanaged causing delays.

Project status is unknown or uncertain. The relationship of current project status to time left to execute is an excellent indicator of the health of a project. Not knowing this relationship may delay taking the appropriate actions; causing them to be too late to be effective or some unnecessary action may be taken.

Project priorities placed improperly – not doing the right things at the right time. This can cause a mismanagement of resources and management attention, which lead to significant delays.

Project managers are unable to accurately assess expenses versus schedule risk. Managers cannot make a solid evaluation of the trade offs to recover from a behind schedule condition. This leads to either being too conservative on cost management, which delays small cost decisions to avoid larger ones later in the project, or too aggressive management, driving resources to meet the perceived deadlines. Both of these behaviors drive costs up significantly.

Critical resources are wasted / capacity is lost. This can be the most detrimental loss to an organization. Once capacity is lost on a critical resource or capacity-constrained resource, it can never be regained and that throughput is lost forever.
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CHALLENGES AND OBSTACLES IN EXECUTION
Managing large projects is challenging work. Experienced project managers understand that even the best-laid plans do not survive the point of execution. Unforeseen events happen. Tasks get stuck or take much longer than planned. Some typical execution challenges include:

- Scope/Requirements change as the project progresses
- Technology changes or fails to deliver
- Vendors fail to deliver on time
- Approvals do not come on time
- Organizational priorities change
- Quality problems cause re-work
- Resources are not available even if promised
- Decision making and planning involve many layers of management with conflicting interests

Without robust execution processes, these forms of variation can be devastating to a project even with a perfect project plan.

THE IMPORTANCE AND ROLE OF PROJECT PLANNING
The purpose of the project plan is to develop and/or communicate the project team’s understanding of the project. Project planning is not a static event, it is the continuous practice of analysis, prediction, and communication. The most important thing the planning process should accomplish is ensure the shortest possible project completion times. How is this achieved? An effective project planning approach accomplishes the following:

IDENTIFICATION OF CRITICAL WORK
The planning process must identify the critical work to be completed. Ensuring that the critical work is scheduled gives a high probability there will be no big surprises during execution due to the missing work statements. This also makes the resource allocation more accurate. If you miss key large work statements and the associated resource allocations, you will understate the load of resources, possibly leading to large delays.

IDENTIFICATION OF RESOURCE REQUIREMENTS
Project plans must identify resource requirements. Without this information it is impossible to know the feasibility of the project duration. It is impossible to know how many resources are required to complete the project and if those resources are available. Knowing this information allows the company to properly staff the projects to give them a better chance of completing on time.

IDENTIFICATION OF SHORTEST POSSIBLE TIME TO COMPLETE PROJECT
Identifying the shortest possible sequence of work is a key step in ensuring the shortest possible delivery times. The shortest possible sequence of work will address both task and resource dependencies.

IDENTIFICATION OF RESOURCE CONTENTION
Identification of resource contention is imperative to making sure a project can be executed as planned. If this is not addressed during project planning, the lack of resources can cause significant delays during execution.
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SYNCHRONIZATION OF WORK
Synchronizing plans to constraint resources properly stagers the introduction of projects. This ensures that the constraint resources will be available to work on the projects when they are needed. This drives shorter actual project completions and makes projected due dates more credible.

IDENTIFYING SCHEDULE RISK
Explicitly stating schedule risk gives project managers critical information, allowing them to focus on the few areas that impact the project delivery date and react accordingly. This helps maintain project due dates.

Good planning processes are robust enough to minimize re-planning efforts during execution. Re-planning depletes management and resource time that is better used to solve problems and recover schedule slips.

Allowances for schedule and technical risk should not be distributed across all tasks; they should be aggregated to provide the most protection and used during execution to focus management attention.

ELIMINATE MULTITASKING
Planning should reduce multitasking, the biggest cause of delays during execution. It is the biggest controllable cause of project delays, wasting time, creating re-work, and increasing project costs. The primary way planning reduces multitasking is by properly controlling the release of projects into the execution system. Through proper control, which begins in planning, you significantly reduce the amount of work in the system. This has the effect of reducing the workload on most resources, which in turn, reduces multitasking.

PROVIDE CLEAR TASK PRIORITIES
During execution, the plan should provide managers and resources clear task priorities within and across projects. In order to make the best decisions, managers must know what the impact would be on the project if they work one task versus another. It should provide clear information on where to direct shared resources to ensure the most rapid completion of the project.

MAXIMIZE SCARCE RESOURCES
The planning process should focus on leveraging the company’s scarce resources, their constraints. Exploiting the constraints produces more throughput for the entire system.

PROJECT EXECUTION METHODOLOGY
Projects are never executed by the project plan; there are many “great” plans, but as we know, there are very few “great” results. The plan is not the result; it is only one input to successful project execution. Project results are the product of a process that includes planning, but the plan is not the goal. In short, only what gets accomplished matters.

Project success is the result of at least four major elements, one
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of which is the planning process. In this paper, we do not discuss the other elements.

The plan’s impact on project execution is centered on these elements:

- Schedule risk is known
- Current status vs. longest chain of dependent events
- Project task priorities based on schedule risk
- Ability to make tradeoffs on expense vs. schedule
- Ability to exploit scarce resources
- Discourages multitasking
- Clearly identifying impact of process (execution) variation on schedule risk

SCHEDULE RISK IS KNOWN
Customers, management, and execution resources will want to understand schedule risk throughout the life of the project, not just during the initial planning period. The key to risk mitigation is a good understanding of the schedule risk itself.

CURRENT STATUS VS. LONGEST CHAIN OF DEPENDENT EVENTS
Communication of current status will help downstream resources effectively plan for upcoming work. Understanding of the longest chain of dependent events will help leaders focus on the right activities.

PROJECT TASK PRIORITIES BASED ON SCHEDULE RISK
Projects need a single prioritization method based on schedule risk as opposed to ad hoc or date-based prioritization. Task level prioritization will provide focus for resources and help reduce task switching which artificially elongates task durations.

ABILITY TO MAKE TRADEOFFS ON EXPENSE VS. SCHEDULE
An accurate understanding of project health aids decision makers in making good choices. Resources and capital can be deployed or re-deployed where it makes the most economic sense.

ABILITY TO EXPLOIT SCARCE RESOURCES
Understanding and exploiting scarce resources will provide maximum velocity of project completions, especially when resources are used across multiple projects.

DISCOURAGES MULTITASKING
Multitasking is the biggest cause of delays that can be controlled. There are two main effects of multi-tasking: delay and loss of capacity (productivity). When a person switches back and forth between tasks, the task switched from waits, delaying its completion. When the person switches back to the waiting task, there is a startup delay to reacquaint them with what they were doing before; in other words, a task setup time. If there has been new information on the task during the delay, some rework and, thus, some additional delay can occur.
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Clearly Identifies Impact of Variation on Schedule Risk
When tasks take longer than planned, project managers must understand the downstream impacts to determine this effect on the overall project schedule. An effective execution methodology will also allow the project team to take advantage of positive variation.

Comparison of CPM to CPPM
The best possible project results will come from a methodology that incorporates the attributes listed above. Before comparing CPM and CPPM against these attributes, let’s understand how they differ from one another. The most important difference between the two is the process for project execution. The execution phase is the key to delivery and the reason many organizations choose the CPPM methodology. Although during the planning process both of these methods identify the critical work that must be scheduled and identify the resources required, CPPM takes extra steps to focus on the work and time required for the limited, constraining resources. CPPM subordinates the planning process to compensate for resource constraints so they may be effectively exploited during execution. The goal of the CPPM process is to leverage these constraints and get the shortest execution time possible, rather than just focus on the shortest sequence of work.

Critical Path Planning & Execution
Most users of CPM have large, complex tasks networks. Defining the work precisely is important, as we have discussed. The underlying assumption behind the requirement to have a lot of detail in the plan is that the more tasks that are scheduled, the higher the probability the project completes on time. These project plans produce a large number of milestones to allow managers to track progress and summary tasks to view sections of projects. Often, it is believed that these milestones provide more visibility into project status. This planning process may provide detailed information about workloads on resources over the life of the project.

During planning, the focus tends to be on the date the tasks must be accomplished rather than their sequence. This emphasis often results in missing many of the critical linkages between separate parts of the project. The schedule then becomes ineffective for managing execution and is only used for communicating (incorrect) information.

The CPM planning process forward schedules tasks to start as soon as possible. This allows for float, protecting the critical path. The tasks in these project schedules are planned with highly probable durations, with safety time built into each. During execution, all tasks must start and finish on time, requiring a complex execution infrastructure.

During execution, as uncertainties and variation strike, the project may fall so far behind that the entire project must be re-planned. This usually requires adding more tasks as additional detail is understood about the activities necessary to complete the project, and a new critical path is created. The planning and re-planning process is very time consuming due to the large number of tasks. Organizations often fail in this aspect, as the prospect of revising the project is unappealing to managers. Additionally, this task is often delegated to the Project Manager or key Resource Manager to perform this extra work. These managers look for shortcuts to manage this process.

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3 Sometimes, this is referred to as the “technical limit”.

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Highly developed CPM organizations spend a lot of time up front preparing risk analysis and contingency plans. While we agree that risk analysis and contingency planning is an important part of executing a project successfully, such planning can result in over-confidence, which means action is not taken when required. Alternatively, if at the first sign of a schedule slip numerous contingency plans are launched, it can cause a lot multitasking, with predictable delay in project completion. To avoid this over-confidence, managers must realize the planning process is only part and the beginning of the execution process.

CRITICAL CHAIN PROJECT PLANNING & EXECUTION

CCPM project plans have the following characteristics and differ from CPM in the following ways:

- Number of tasks in a CCPM project network are fewer
- Emphasis on identifying and quantifying project deliverable integration points
- Explicitly finite loading based on known resource availability
- Explicit definition of normal schedule risk as a separate element in the project plan
- Task planning to start as late as possible
- Planning project starts based on constraint resource availability

Placing CCPM provides project plans that generally have far fewer tasks (than traditional methods) to manage during execution. The emphasis is to capture key integration points and activities that require known resource constraints. It can include key milestones or customer handoffs where progress payments are earned. The plan strives to be good enough to reasonably determine the project completion date, allow for sufficient resource planning across projects, and schedule at a task level of detail just enough to where small deviations can not affect the plan. For example, if you live 20 miles from work, you estimate the task to drive the 20 miles – not plan each mile along the way, essentially summarizing all the positive and negative variation that can occur.

CCPM plans level resource loads to available capacity for the project. Resource level loading at the project level and across all projects in the system reduces the probability of multitasking, reduces WIP, and thus increases flow. CCPM provides a plan that is both task and resource dependent – the critical chain. Scheduling this way reduces the possibility of needing to re-plan during execution due to resource limitations.

The plan uses task durations that have a 50% probability of being achieved. The safety is removed from each task, aggregated, and placed to protect the project due date and the critical chain from variation. Aggregation theory allows us to use less protection at the end of each chain of events, allowing for a shorter schedule. These buffers are not like float; rather, they are calculated and strategically placed to protect the project and critical chain. They are used to prioritize work and management attention during execution.

This prioritization can also allow for less time up front performing risk management. When the buffers are consumed too fast, this identifies where risk must be mitigated quickly. Because management is not re-planning, and multitasking is reduced, managers have the time to mitigate when necessary and only when risks evolve. There is less of a need to plan for all potential risks; of course, there are always known risks that must be addressed at project start.
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A CCPM plan schedules task start dates as late as possible, while allowing for practical management of schedule risk. This delays any expenditures while protecting the project due date, and also reduces multitasking. Using these techniques, this project schedule becomes a schedule with buffers to protect the longest chain of linked activities, to ensure the project due date is met.

MULTIPLE PROJECT SYSTEMS

Another element of CCPM project management planning is the process of pipelining projects into the organization. Pipelining is the process of scheduling the start of a project based on the system’s capability to absorb the work. The start of any project is generally based on the availability of a constrained resource or major integration or assembly point, controlling the rate that projects are released into the system. Projects do not start ASAP; they begin when the system can support the release of the new work. This keeps WIP to a minimum and further reduces the possibilities of multitasking, which increases the velocity of work through the system. Reducing WIP reduces the time a task waits for a resource to get started, allowing tasks to complete faster. Project lead times become shorter, with more work accomplished in the same amount of time.
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CPM & CCPM EXECUTION CONTRAST
Typically, projects would be executed using the critical path. For example, below is a small project network.

Note the critical path is through the “X” leg of the network. Therefore, the execution sequence would be this:

Starting with A - the project is finished after 50.

starting with B - the project is finished after 40.

Following the critical chain, the project executes in 10 fewer days, or 20% sooner, with the same resources.

MANAGING SCHEDULE RISK WITH CCPM
CPM assumes there will be variation a project must endure during execution. By planning correctly, most variation can be absorbed without the need to re-plan during execution. The primary focus is tasks that are penetrating the buffers to the extent that they require management attention, that is, the ones causing penetration into the red. If there is significant penetration into a buffer, generally there are few tasks to review to determine the best course of action. CCPM identifies which tasks are causing or have caused increased schedule risk and provides the mechanism for
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management to focus its risk mitigation and project recovery plans. It identifies where redeploying resources can have the needed impact to improve the schedule. This improved decision-making capability drives the performance of the entire execution system.

During execution, CCPM focuses on the overall progress of the project; it is not concerned with managing start and finish dates of tasks. With the probabilities of task estimates being closer to 50%, it is understood most tasks won’t be finished as scheduled. As tasks are completed and buffers consumed, the project manager can track the progress of the overall project based on reviewing the health of the buffers. CCPM concedes there are some key tasks that may require the finish dates to be managed but these should be as few as possible.

The CCPM execution process makes it clear when management’s attention is required: when the ratio of work remaining and buffer remaining reach an action threshold; the red zone. The graphic above illustrates a project’s life, and the times when adjustments were necessary.

**MEASURING UP**

By understanding some of the differences between CPM and CCPM it is now possible to make a measured comparison. How does CPM and CCPM measure up against the desirable attributes of a good project planning and effective execution process?

Both methods require software to identify current project status. The critical chain functionality is not found in many of the popular project management packages. This “scarcity” causes some managers to try to use CCPM without it. Although it is possible to manually calculate the critical chain, it is not practical. For planning, the software identifies the shortest path to level load the resources, identify task dependencies, and calculate the critical chain. It then calculates the size of the buffers and places them at integration points and the end of the project.

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The table below summarizes the differences between the two methodologies:

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**Using Dates and Contractual Milestones**

In many environments, there are tasks associated with dates that must be managed: contract compliance dates, supplier delivery dates, payment dates, and so on. The critical path algorithm does not address these requirements. The chain algorithm in several CCPM software packages does consider project milestones. In planning the critical chain, they become required tasks. We advise that these are as few as possible because they can increase the length of the chain and subsequently, the duration of the project. However, if the project process requires specific milestone dates, they may be tracked and managed.

Additionally, specific dates and progress reporting are often used to report project status to management and customers. There are legitimate reasons for reporting dates, but this is not one of them. The question that customers and management really want to answer is, “will my project be on time?” This is essentially a risk management question that CPM cannot answer⁴, but the critical chain methodology answers in an unexpected way. CCPM tells management both the status of the project (as determined by the % of critical chain complete) and the risk of completing on time (as a % of project buffer consumed). This is sometimes confusing for those who receive this information; they do not know how to interpret it.

CCPM plans typically use floating milestones (and associated dates) to update the management information systems when just the dates need to be tracked. The methodology can accommodate contractual milestones (fixed dates), which are managed using the buffer incursion methodology and chart similar to the one shown above.

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⁴ Many project managers use float to assess project delivery risk using a CPM project plan.
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Passing the expected completion dates and final completion dates to an enterprise project management system can drive the billing and supply chain management systems.

COMBINING THE TWO APPROACHES

The critical path is a useful method to answer the question, “How quickly can the project be completed if I have no resource constraints (the technical limit)?” The answer to this question essentially produces a technical evaluation of the project’s feasibility. It tests the relationships of the work. The answer to this question provides an input into risk planning or feasibility assessment. Both approaches require this step of understanding the work and identifying the “best possible” sequence of work to ensure the shortest project completion time.

Managers should not fool themselves into thinking this “best possible” plan is something that is usable for execution or that the completion dates produced will be achieved. No one has an infinite supply of resources. There is imperfect knowledge of future events. Therefore, any plan will be a forecast of a possible outcome. The key to achieving project success is acknowledging that the plan is a forecast (with imperfections) and this forecast must be managed to achieve the results that are needed. This is where the critical chain method excels in producing useful results.

In short, the critical path is a useful tool to answer a specific question; knowing the answer to this question is a part of successful project completions, but it is incomplete. Critical Chain Project Management completes the equation.

CONCLUSIONS

This paper illustrates the differences between CPM and CCPM project planning and execution methodologies. The most important difference between the two is the execution process provided by CCPM. In this regard, the CPM method is incomplete. Managers have been working with this inadequacy for quite some time, with the poor results to show for it. In addition, the CCPM and CPM planning methodologies differ in their approach to managing (normal) schedule risk and planning resources. Thus, most of the benefits of the CCPM execution process cannot be gained without incorporating the planning processes as well. CCPM planning and execution implementations have a strong record of increasing the performance of project organizations.
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ADVANTAGES OF EACH

CCPM offers the following advantages:

• Identifies the critical work sequence, especially the work of constraint resources
• Reduces WIP in the system, which speeds up work completion
• During execution, identifies the risk associated with each task and its impact on the project completion
• Clearly identifies when management must take action and what actions to take
• Exploits scarce resources

• There is far less re-planning during execution, allowing management to focus on managing variation
• Projects are completed 25-30% faster than conventional project management approaches

CPM offers the following advantages:

• Identifies the critical work sequence
• Provides resource requirements
• Drives the Earned Value System (EVS)
• Is the generally-accepted solution

DISADVANTAGES OF EACH

CCPM has these disadvantages:

• Resource loads are understated, making raw numbers difficult to interpret
• Feeding EVS can require extra steps
• Is relatively new; there is a learning curve to master the process
• Requires unique software

CPM has these disadvantages

• Execution can become a constant exercise in re-planning, which distracts resources from the real work
• Does not easily define the impact of schedule delays
• Does not clearly point management to the tasks that need their attention
• Can drive WIP with early start schedules
• During execution, the critical path changes, making it difficult to manage priorities
• Does not exploit constraint resources

FINAL THOUGHTS

While it is clear that CCPM presents a superior solution, external factors may make it impossible to fully disengage from CPM. In these cases, it is possible for CPM and CCPM to coexist. It is important to understand that CPM has no execution methodology; therefore, CPM should subordinate to CCPM during execution in order to achieve the highest probability of on-time, on-scope, and on-budget project delivery. To provide optimal results and avoid conflicts during execution, this coexistence must be thoroughly understood and properly designed into the overall project management process.

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