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## IDENTIFYING THE CRITICAL PATH

TCM Framework: 7.2 – Schedule Planning and Development, 9.2 – Progress and Performance Measurement, 10.1 – Project Performance Assessment, 10.2 – Forecasting

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### INTRODUCTION

#### Purpose

This recommended practice (RP) for *Identifying the Critical Path* is intended to serve as a guideline and a resource, not to establish a standard. As a recommended practice of AACE International it provides guidelines for the project scheduler when reviewing a network schedule to be able to determine the critical path and to understand the limitations and assumptions involved in a critical path assessment. Such a determination is a part of the total cost management (TCM) project planning, scheduling forecasting, and change management processes.

#### Overview

This RP focuses on the types of prospective analyses performed in real-time while the project is underway, the advantages and the limitations of each in identifying the critical path of network schedules. The identification of the critical path and understanding what calculations and settings went into making that identification is a critical first-step in the schedule analysis process. Other recommended practices discuss analysis of schedule trends and the issues involved with plan changes intended to modify the critical path.

The work breakdown structure (WBS) is used to break down (or decompose) a project into all component activities necessary to deliver a complete and functional project for the stakeholders. The critical path method (CPM) is used to apply logic to determine sequencing of those activities to form an activity “network,” and then mathematically determine activity timing. The mathematical calculation determines the earliest time that an activity can start in a calculated “forward pass” through the network. The latest time that an activity can start is determined by calculating the network in a “backward pass.”

There are various accepted methods for determining the critical path. This RP describes four such CPM methods and explains the calculations used in these methods. It assumes a working understanding of the CPM calculation process.

This RP also discusses the analysis of the output of a CPM calculation. There is no absolute standard or definition of “proper” CPM calculation procedures or a list of required or optional rule extensions. No professional organization or standards testing bureau currently evaluates, certifies or validates CPM software algorithms or procedures. Identifying the critical path requires an understanding of the methods and algorithms used by the various software platforms in producing the CPM calculations.

Different CPM software products can produce different calculation results when applied to the same schedule. A project scheduler must understand the differences and nuances of the software tools they will most often encounter and be prepared to account for the same in their analysis. In addition, different CPM calculation options from the same CPM software can produce different results for the same schedule logic. This RP provides an analysis of the output and identifies the strengths and weaknesses of the processes used to obtain those results.

This RP acknowledges that identification of the critical path is likely made via various software products. Specific software is identified in this RP in order to qualify these methods and algorithms. In the interests of accuracy, only those platforms where the authors have expert knowledge are cited here. This does not constitute a recommendation of any particular company or software product. References to other software platforms may be added to this RP as they become available.

**RECOMMENDED PRACTICE****Critical Path Analysis**

The critical path is defined as the longest logical path through the CPM network and consists of those activities that determine the shortest time for project completion. Activities within this or list form a series (or sequence) of logically connected activities that is called the critical path. A delay to the start or completion of any activity in this critical path results in a delay to project completion, assuming that this path consists of a continuous sequence of activities without an overriding date constraint or multiple calendars.

Normally, there is only one critical path through a network schedule. There may be multiple critical paths through a schedule. Multiple critical paths may occur due to different paths having exactly the same overall duration. Constrained milestones (perhaps reflecting contractual requirements) may cause different paths to be critical at the same time. Individual schedules (each with their own critical path) may be combined into a master schedule that has a different critical path. In the case of a master schedule, there are both individual schedule critical paths as well as a larger program critical path. Project schedule specifications should define the legal interpretation of each type.

Another type of critical path is called a “resource critical path.” As there are rarely unlimited resources available to the project team the constraint of limited resources often strongly influences the critical path calculation. Therefore, in addition to the standard CPM calculations and logical connections, there is an additional, implied constraint of limited resources. In a resource critical path, after CPM network calculations have been made activities are further delayed, interrupted, or accelerated to reduce the overall daily unit resource requirement to some predetermined resource limit. This may be accomplished by adding preferential (or soft) logic, by manual or automatic resource leveling, or just by the physical resource limits imposed or utilized on the project without prior planning. While many aspects of standard critical path analysis are pertinent to resource critical path analysis, this RP does not further address the subject of a resource critical path. This RP does not address schedules that contain settings that force the activity durations to be calculated by resource availability, as in resource-driven schedules.

Successful project schedulers must determine and communicate activities that are critical, as well as those that are near-critical (see later discussion in “Near-Critical Activities/Paths”), in a CPM schedule. Management by exception<sup>[1]</sup> processes dictate that project management should devote more attention to maintaining the required production level for activities on the critical path than for other activities further removed from criticality. Further, recognition that duration estimates are not absolute and susceptible to variation requires that a critical path analysis should also include the review of near-critical paths. Both of these topics are addressed in more detail later.

The list of critical path activities often changes from schedule update to schedule update as activity status is revised and the schedule is recalculated. Any activity associated with the CPM schedule that is delayed long enough can eventually become critical, regardless of its original status.

There are several accepted methods for determining the critical path. The four most frequently used methods include the following,

1. **Lowest Total Float** – The activities with the lowest total float (sometimes abbreviated as “TF”) values may be considered critical path activities. This calculated value may be a positive number, zero, or even a negative number.
2. **Negative Total Float** – Using this classification method, any activity that has negative float is considered critical, even if other activities have a lower negative float value. Under this classification, if an activity is contributing to late project completion then it is worthy of inclusion on the critical path list regardless of its direct contribution to delayed project completion. Another way of framing this

concept is to say that any work is understood to be critical if it scheduled to be completed after the date required for a timely project completion.

3. Longest Path – The concept and term, “longest path” has existed since the beginning of formal CPM theory. Commercial implementation of this process into a defined algorithm has only recently been made and is recommended for projects that use multiple calendars and activity constraints.

The longest path calculation begins by identifying the activities that have an early finish equal to the latest calculated early finish for the project and then identifies all driving relationships for these activities and traces them back to the project start date. This special calculation scheme is currently only instituted in Primavera scheduling software products. When discussing the theory of longest path, we will use the phrase using lower-case letters. When describing the Primavera software feature called, “Longest Path,” we will use upper-case to distinguish the implementation from the theory.

4. Longest Path Value Method - The principle of longest path value differs from the approach used by Primavera in that, instead of just noting activity inclusion or exclusion from the longest path, a numerical value is calculated for each activity that describes the degree of longest path much like float describes the degree of criticality. Other principles are also enforced that will be described below.

While very similar, the terms “TF critical path” and “longest path” are used in slightly different contexts. The purpose and major use for longest path is to describe the shortest path to finishing the work necessary to complete the project. Acceleration or deceleration of work on the longest path activities will have an effect on project completion. In contrast, if external project constraints and/or contractual issues involved in the use of constraints are applied, they will influence direction of the critical path through the project schedule. The critical path defines project priorities and displays the complexities involved with late completion throughout the project, especially when multiple milestones are involved. In short, longest path describes the work sequence with the greatest total duration. The critical path can be used to perform the same function but also incorporates other project restrictions that may or may not be related to project completion.

There are exceptions caused by constraints to each of these calculation methods and technical issues that result from using any of these critical path analysis methods in various software tools. This RP will discuss each method in detail.

### Lowest Total Float

The lowest total float method identifies the critical path activities as activities that have the lowest float value in the schedule. For the purposes of this RP, “float” is synonymous with “total float.” Activity float is computed by subtracting its early finish from its late finish, or by subtracting its early start from its late start<sup>[2]</sup>. Sometimes float values for a sequence of activities will vary depending upon which float computation method is used.

Solely using float to define the critical path is often confusing because the use of constraints, calendars, and sequencing methods often results in the logical chain of critical path activities not all having the same float value. Sequential activities may be affected or activities with logical relationships on the critical path may have different float values for the following reasons:

- Date and float constraints
- Activity calendars
- Lag calendars
- Interruptible activities
- Hammock, level of effort, WBS, and other types of summary activities

- Open-ended activities
- Out-of-sequence progress
- Total float calculation method
- Resource leveling

### *Constraints*

A major complication to critical path identification is in the use of constraints. Constraints may be defined as any feature or aspect of the schedule that externally affects the sequencing or timing of an activity. In this RP, the term “constraint” refers to date and float constraints and not to logical constraints (relationships.) In this context, a constraint is an overriding requirement or setting that influences the CPM calculation of activity day numbers and their subsequent calendar dates.

Scheduling software constraints may artificially change the float value(s) for an activity or string of activities by overriding network calculation results. Constraints can directly or indirectly change the float of an activity or network. With constraints, any group of activities may be “forced” to appear to be on the critical path, or constraints can be applied so that no activity in the entire project has zero float. As an example, constraints used to assure that a certain activity should be performed prior to the onset of expected bad weather may cause the critical path to end on the constraint date of that activity.

Some constraints only affect forward pass CPM calculations. Examples of this are “start-no-earlier-than” and “finish-no-earlier-than” constraints. These types of constraints determine how early an activity may be scheduled but do not affect how late they may be scheduled. Other constraints only affect backward pass CPM calculations. These include “start-no-later-than” and “finish-no-later-than” constraints. These types of constraints determine how late an activity may be scheduled but do not affect how early they may be scheduled. Some constraints affect CPM calculations in both directions, such as start-on or finish-on constraints. These types of constraints set exact dates for occurrences unless CPM logic forbids the result. A fourth type of constraint is called a mandatory constraint. This type of constraint forces a start or finish date to be observed even if CPM logic otherwise forbids the occurrence. This RP strongly recommends against the use of mandatory constraints as they lead to illogical results where activities are scheduled to occur even if preceding work is incomplete.

The only exception to the prohibition against using mandatory constraints would be when used to reflect a contractual requirement to not start or finish any earlier as well as no later than a certain date. Most contracts allow for early completion, and thus a mandatory finish constraint would be inappropriate in that instance.

Other constraints not discussed in this RP include total float and free float constraints that pre-determine the respective float values. An expected finish “constraint” is not really a date constraint but instead an automatic activity duration adjustment.

With some CPM software, constraints may be assigned to the project as well as to an individual activity. The project constraint will affect the activity or activities with the latest early finish date. Project constraints are particularly difficult for the analyst to discover as the setting is only observable by reviewing the project summary tab. It is recommended that individual activity constraints to the project finish activity be used instead of project constraints for this reason.

Use of constraints may be hidden and systemic. For example, when a user wishes to have the software schedule all uncompleted work no earlier than the current status date, Microsoft Project™ software simulates data date considerations by automatically assigning all uncompleted activities scheduled to be finished prior to the data date with a “start-no-earlier-than” constraint.

Constraints may also be used to delay activities for resource leveling considerations. Unless meticulously documented and maintained, this practice may easily cause confusion and is likely to produce unintended

consequences in CPM calculations. This RP strongly recommends refraining from the practice of using constraints to reflect resource constraints.

### *Activity Calendars*

Activities in the same logical chain (or string of activities) operating under different work calendars may have different float values. For example, a concrete pad is constructed with a structural frame being erected on the slab as soon as the concrete is sufficiently cured. Concrete is placed during a five-day workweek, while curing takes place on a seven-day workweek calendar. In the case where the slab reaches its cure period during a weekend, the next activity cannot start until the following workday associated with that erection activity. In this simple, three-step process, the float of the middle activity (curing) is different from its predecessor and successor. Were this chain of activities to be on the critical path, the lowest total float method would improperly conclude that the curing activity (with its higher float) would not be a member of the critical path.

### *Lag Calendars*

In Primavera and Microsoft CPM software products, lags are relationships with time durations that act exactly like non-interruptible activities. Even though a lag acts like an activity, currently only Deltek's Open Plan™ CPM software allows for the assignment of different work calendars to individual relationships. The others may allow different calendars to be assigned, but this single assignment applies to all relationships and not to individual relationships. In the vast majority of the cases, the CPM software will use one calendar setting for all relationships in the program. Options for defining relationship work calendars may include the predecessor activity's work calendar, the successor activity's work calendar, the default work day calendar, and a continuous (non-holiday) work day calendar. No single setting works perfectly for all relationship lags and thus relationships may be modeling the wrong work day calendar and exhibit incorrect float.

Other software packages calculate lag on the activities and not on the relationship. Asta Project™ CPM Software calculates the lag from the start or finish of both the predecessor and the successor. The relationship is a straight link between the two lag points. Because a lag may be driving or non-driving, the lag adopts both or either of the predecessor or successors calendars depending on circumstances.

### *Interruptible Activities*

Interruptible Activities are activities that are both logically constrained to start at one period and constrained to finish on another. If the two opposing logical constraints do not neatly fit with the fixed duration for that activity, then the start of the constrained activity may be delayed to satisfy the finish constraint and activity duration. In this case, the start float value indicated may be considered to be incorrect as the activity could start earlier except for implied requirement for continuous work.

This condition may be further complicated by the ability of some CPM software programs to allow these "continuous" duration activities to become "interruptible" activities by automatically stretching the activity duration to fit both logical constraints. Interruptible activities in this circumstance have a longer planned duration than the established original duration estimate and the float value calculated using start dates may be different than the float values calculated using finish dates.

### *Summary Activities*

Hammocks, level of effort, and WBS activities are not really activities at all but rather are place holders that summarize the time interval and total float of a group of other activities. If the activities at the start of

the time interval have a low total float value but the ones at the end have high total float, which values should be used for the hammock? Possible choices include the lowest, average, or highest float in the group being summarized or the float of the earliest or latest activity. None of these choices is optimal in all circumstances. The float shown on these summary activities generally does not indicate the relationship of the activities being summarized to the critical path.

### *Open-Ended Activities*

Schedule activities that do not have either a predecessor or a successor are said to be “open-ended.” Aside from the one activity starting the network and another finishing the network, open-ended activities “break” the logical network sequence and may not exhibit correct float calculations. Some CPM software such as those published by Primavera can automatically cause open-ended activities to be critical path activities even though they are not on the longest path. During schedule calculations, overlapping activity relationships, such as SS with lags, FF with lags, and FS with negative lags, that do not provide a relationship tie to/or from the balance of that activity, may cause a portion of the activity to become open-ended.

### *Out-of-Sequence Activities*

Actual activity progress may override CPM calculation considerations. When actual progress occurs in activities that should not logically begin due to incomplete preceding activities, this is termed “out-of-sequence progress.” The ability of CPM calculations to incorporate and consider the time implications of out-of-sequence progress on activities is essential when considering the activity’s float value. Possible methods to incorporate progress overriding logical necessity include:

- Retained Logic – The data date and all logical relationships are considered and out-of-sequence work is automatically suspended until all logically preceding work is complete.
- Progress Override – The data date is considered but any predecessor relationship to the out-of-sequence activity is completely ignored by the CPM calculations. Note that this does not prevent the software from displaying such relationships as if they were still was in effect.
- Actual Dates – This is a hybrid of the above two methods that retains the predecessor logic if the activity has started out-of-sequence but ignores it if the out-of-sequence activity finishes.
- Constraining All Early Activities – Microsoft Project optionally allows the scheduler to set a status date and then change the CPM calculation options to assign start-no-earlier-than the status date constraints to all unfinished activities that would otherwise show planned work before this date.
- Ignoring the Data Date – By default Microsoft Project ignores status date considerations, thus ignoring the ramifications of out-of-sequence progress. This RP recommends against using any CPM calculations for analysis that do not take into consideration of the effects of the status date to planned work.

This RP recommends the use of retained logic CPM calculation mode due to the fact that logic override can create orphaned predecessor activities and disregards listed constraints. If the retained logic method produces poor or inaccurate results, then the logic of the network should be corrected and not the CPM calculation mode.

### *Total Float Calculation Method*

Total float can be measured by subtracting the early start workday from the late start workday (called “start dates float”), by subtracting the early finish workday from the late finish workday (called “finish dates float”), or by taking the lowest value from using both methods. Some scheduling software allows the user to select start dates float or finish dates float for computing total float. Whichever software setting used,

the same calculation routine is used for all activities in the schedule. No one setting gives the best answer in all circumstances.

### *Resource Leveling*

Resource leveled schedules usually do not show correct float values. Thus, the total float method does not identify the correct critical path(s). After the schedule model has been calculated, resource leveling routines override early and late start dates of leveled activities, scheduling them when resources are available. Other successor activities are subsequently delayed to maintain network logic. Some CPM software may adjust float values to reflect reduced float caused by delaying activities, others do not. In either case, the resource-constrained float values displayed are incorrect. In a resource-restrained schedule, the concept of float, as the software displays it, breaks down and quite often the concept of a critical path breaks down.<sup>[3]</sup> This previously undefined resource-float has been called "phantom float" by Fondal and others.<sup>[12]</sup>

### *Risk-Adjusted Critical Path*

With the advent of the wide acceptance of CPM Monte Carlo simulations, it is possible that non-deterministic activity durations might be considered when evaluating the critical path. This mostly unknown branch of analysis has been proposed<sup>[11]</sup> and called "risk-adjusted critical path."

### Negative Total Float

One of the competing legal applications of concurrent delay says that delay to any work exhibiting negative float that occurs independently and at the same time as another delay may be considered a concurrent delay. The reasoning is that but for the other delay not occurring, then delay to the activity with negative float (and not necessarily the lowest float) would have delayed the project as well. In this case, negative float is used as qualifying criteria for project delay consideration.

While this definition of a critical path (and thus concurrent delay) is not as universally used as the concept of lowest total float, it must be considered if the contractual language defines it as the technique to be used.

### Other Float Issues

The following list is a partial list of different float types:

- Total Float – The amount of time an activity can be delayed without delaying the early finish of the project or any constrained activity.
- Free Float – The amount of time that an activity can be delayed without affecting the early start of any succeeding activities.
- Independent Float – The amount of time that an activity may be delayed without affecting the early start or early finish of any succeeding activities.
- Junior Float – The lowest free float of all preceding activities.<sup>[4]</sup>

Free float may be used as an indicator of possible missing logical relationships. Activities with a high free float value indicate that they may be performed nearly independent of the rest of the project. While this is certainly possible in any project, proper timing of work is very important for efficient performance. Experience has shown that nearly independent work in a project is relatively rare and thus a high free float value often identifies missing logical relationships.

High free float values may occur due to the natural tendency of work tasks to correlate with a large number of activities. It is usually not practical to include every possible relationship from every activity to related tasks. With the understanding that a CPM schedule is only a working model of the actual work plan, schedulers reasonably tend to only include logical relationships that they feel are significant. This leaves the possibility that a significant relationship was overlooked and left out of the schedule as insignificant, leaving an activity with more free float than is warranted. Before determination of the critical path is made, all instances of high free float values should be investigated for missing successor relationships. If the total float values are reasonable, when late dates are displayed, the resulting schedule should still demonstrate achievable construction sequencing and durations.

For a float value to be correct, the network schedule model must consider the data date and the individual activity's actual status. Activities that do not have actual start dates and/or actual finish dates cannot exist as planned activities prior to the data date. Actual start or actual finish dates cannot fall after (or later than) the status date. These types of conditions are illogical and may invalidate any float values derived from such a schedule.

### *As-Built Float*

As-built float is a time estimate of the activity's float at the time the work actually occurred. If the project's status were noted and entered every day on a project and the CPM was then recomputed, then the as-built float would be the daily total float reading for any activity that was on-going or could logically start but had not. This value is completely different than total float or free float. Current scheduling software is not designed to calculate or display this value or values. Since CPM is a dynamic measurement of the interactions of activities as unequal progress occurs and other events (planned or unplanned) transpire, this measured value may actually change from one time period to the next, even within the same activity. This measurement is much more dynamic than just the difference between the predecessor activity's actual finish and the activity's actual start, although this is a factor.

The problem of using total float to determine the critical path is further compounded when relating similar activities together in a "float path." In theory, activities directly related to each other with the same float value can be grouped together and considered as an entity called a "float path." The most famous of these float paths is the "critical path" where the float value is equal to zero (or the lowest float value.) Unfortunately, this literal approach sometimes causes incorrect critical path assessment simply due to activities being shown as hammocks, being interruptible, having different work calendars, having completed, having constraints, or how the relationships were modeled. Review of as-built float may be useful in identifying the critical path in these situations.

### Longest Path

"Longest Path" is defined by Primavera Systems, Inc<sup>1</sup>, as the string of activities that "have an early finish equal to the latest calculated early finish for the project".<sup>[5]</sup> Primavera CPM software identifies all driving relationships for these activities and traces them back to the project start date. In general, the Primavera Longest Path only considers "forward pass calculations" and returning controlling relationships and does not concern itself with "float." This process includes activities that might otherwise be left out by the lowest float method definition of critical path.

Primavera defines a driving relationship as: "a relationship between two activities in which the completion of the predecessor activity determines the early dates for the successor activity." Software such as Primavera Project Planner™ (P3) uses an asterisk ("\*") in the predecessor or successor window to denote the fact that a particular relationship was a driving relationship. Longest Path has been implemented in all Primavera CPM software including SureTrak™, P3™, Contractor™, and Primavera

<sup>1</sup> Longest Path was introduced in P3 for Windows Version 2.0b and is now implemented in SureTrak as well as the Primavera Enterprise software.

Enterprise™ (currently also called P6™.) This RP assumes that the algorithms used in each of these implementations are identical and give identical results.

Just as with the CPM, the determination of the Longest Path is a process. Using CPM forward pass calculations, it identifies the last activity in the schedule and then works backward identifying all longest path activities using their driving relationships. This list or chain of noted activities comprises the Longest Path.

Primavera's Longest Path identification is only the starting point for this analysis. Consideration must be allowed for:

- Limited inclusion of activities. Only the activities identified as being on the Longest Path are noted. There is no provision for analyzing how close other activities are from being included in this list.
- Sensitivity to constraints. Constraints (such as start-no-earlier-than) that affect the forward pass calculation also affect the Longest Path. Constraints of this nature can invalidate the Longest Path by causing it to occur only in the future and not proceed from the actual data date.
- Sensitivity to CPM calculation modes. Primavera's Longest Path is determined based on the schedule calculation method selected. If the schedule has been calculated based on progress override, the Longest Path only identifies activities that have not been affected by out of sequence progress.

### Longest Path Value

The longest path value™ method identifies the longest path from the status date of the project to completion by a manual method<sup>[6]</sup> or by using a third-party software product. This technique uses a number instead of just an on/off indicator to identify membership on the longest path. The principle used is similar to the Primavera Longest Path method but differs from this approach in the following ways:

- No logical relationships are ignored, even those to completed activities. In effect, this means that longest path value always uses retained logic CPM calculation mode. Progress override CPM calculation setting will cause the longest path backward trace process to ignore predecessor relationships from started activities.
- The "forward pass" is made without consideration of constraints. The consideration of constraints in the longest path may cause the longest path to begin much later than the status date. This violates the basic concept of a continuous path from the status date to project completion.
- Lag durations are always computed using the calendar of the predecessor activity.
- The backward longest path analysis begins with the designated substantial completion activity. If a substantial completion activity has not been designated, then the longest path should begin with the activity with the latest early finish. The longest path must proceed through the substantial completion activity in order to be valid. Any activity that logically occurs after the substantial completion milestone should be not be considered as being on the longest path.

### Near-Critical Activities/Paths

While critical path activities require elevated management attention to ensure timely project completion, exclusively concentrating only on critical activities is unwise. Planned activity durations are only estimates. Over time, the critical path changes as the status changes. Acceleration and completion of critical path activities will eventually lead to other activities becoming critical to project completion that were not previously critical. Delay to activities that are not on the critical path may also lead to them becoming critical.

Activities that are not critical but may easily become critical are called “near-critical” activities. Near-critical activities must be identified by the project scheduler and their status monitored as well. Just like critical activities, near-critical activities may be identified in multiple ways;

- Near-Critical Float
- Near-Longest Path
- Longest Path Values Greater Than Zero
- Multiple Critical Paths

#### *Near-Critical Float*

Near-critical float is typically defined as float values within a set range just above the critical path float. If the critical path activities had a float of zero, then near-critical activities might include all activities with a float value of 1 through 10. Another method of determination is the 5% rule. Any sequence of activities whose float is less than 5% of the remaining duration could be considered near-critical. A third possible rule is to use a maximum float value equal to 50% of the average reporting period.

#### *Near-Longest Path*

Comparable to near-critical activities (those activities with a low float value approaching the critical path), near-longest path activities must be examined in a similar fashion.<sup>[7]</sup> There currently exist two different methods for determining this: longest path value and multiple critical float paths.

#### *Longest Path Values Greater Than Zero*

An algorithm<sup>[8]</sup> can be used to compute an actual value of the longest path for every activity in a CPM schedule. Activities with a longest path value equal to zero would be “on” the longest path. Once computed, the activity longest path value can be used like total float was to identify near-critical activities, modified as listed as listed below:

- Longest path values within a set range such as from 1 to 10
- Longest path values within 5% of the remaining project duration
- Longest path values less than 50% of the average reporting period

#### Multiple Critical Float Paths

This concept was introduced in 2004<sup>[9]</sup> and implemented in Primavera’s Enterprise version 5 scheduling software in 2005. Determination of a path number is made using either total float or free float. Using either criteria, the algorithm traces the lowest float value from an identified completion activity backward to the start, iteratively identifying paths using the most critical resulting successor float, and then assigning a corresponding float path value.

Calculating multiple paths using the “free float” setting will result in a primary critical path that is identical to the critical path displayed when critical activities are defined as the longest path. All subsequent float paths will be increasingly distant float paths from the longest path. The amount of difference between float paths (or measure of near-criticality) is not presented but may be inferred using total float.

Calculating multiple critical float paths does not affect how critical activities are defined. This definition is set before CPM calculations as either by a maximum float time or by longest path. The definition is used in determining how the bar chart (Gantt chart) view displays colors and identifies critical activities.

### Interpretation of the Critical Path

Acceptance of the level of criticality in software-calculated critical path activities should not be made automatically. The value for each activity should be considered for reasonability and quality of measurement. The greater the level of uncertainty about the durations estimated or the interrelationships between work tasks, the more inclusive the list of near-critical activities should be when considering critical path activities.

Only activities that denote work or physical time constraints should be included in the list of critical path activities. Summary activities such as hammers, level of effort, and WBS summary activities should be excluded from this list as they were not actually involved in the CPM calculations.

Activities should be validated before accepting them as members of the critical path. When reviewing the list of critical path activities, project schedulers should ask,

- Has the critical path activity been stated correctly?
- Is the time allotted for the activity reasonable and in accord with any contract or specifications?
- Does the logic shown in the schedule reflect current conditions as of the status date?

The estimate of remaining duration of the activity should not reflect allotted time but should reflect an honest estimate of the remaining work in accordance with the project execution plan and applied or available resources. In the case of a cost loaded schedule, the percent complete data field should not be used to calculate the remaining duration unless the activity costs truly represent time related costs that will be earned proportionally to time spent. If this is not the case, then the percent complete value for the cost earnings should be updated independently and the remaining duration value updated based on remaining work.

Long-duration activities on the critical path should be given more scrutiny. Activities based upon commitments (such as activities representing manufacture or delivery of major equipment items) should have their completion dates verified instead of just assuming no change to delivery dates. Certainly, the estimated completion date of these activities should not improve or degrade from earlier estimates without such verification.

Other long-duration critical path activities should be re-estimated and perhaps broken-down into smaller components for better understanding and increased duration accuracy. An activity representing intermittent work should not normally be modeled to be on the critical path but should be broken-down into smaller work units that can be estimated as continuous work. Interruptible activities that have been automatically "stretched" by the CPM algorithm should be carefully considered before being reported as part of the critical path.

If a large percentage of the total activities in the schedule are critical or near-critical, then management by exception (managing a project by primarily focusing on the critical aspects) becomes very difficult to apply. It is possible for a legitimate project to have a large percentage of critical activities and this percentage does tend to increase as the project nears completion. Even so, the likelihood of inflated duration estimates and invalid logic climbs as the percentage of critical path activities to the total rises. There is no set definition for the recommend maximum allowable percentage of critical and near-critical activities, especially once a project begins. This "allowable" percentage would vary based on the type of project, especially when trying to compare relatively linear projects like transportation projects to more internally complex projects like facilities.

Activities on the critical path that are related using start-to-start or finish-to-finish relationships may find that only the start portion or the finish portion of the activity is truly on the critical path. Perhaps only the first two days of a 10-day activity are actually critical. In circumstances such as these, changing the float calculation rule from using start dates to using finish dates may radically change the activities shown to

be on the critical path. Some CPM software has the option of choosing the “most critical” result of using both rules.

For proper analysis of activities on the critical path, likely candidates should be logically constrained by both a predecessor relationship to the start of the activity and a successor relationship to the end of the activity. Other relationship types exist and those combinations not meeting the above criteria could result in questionable critical path results.

The reviewer of critical path activities should also consider invalid or unused logical relationships that may skew results, making activities appear critical when they actually were not. The reviewer should consider revisiting the critical path analysis produced from earlier status updates if particularly noteworthy relationships were in fact observed to not be applied in the actual execution of the project.

## REFERENCES

1. Clough, Richard A., Glenn A. Sears, and S. Keoki Sears, *Construction Project Management, Fourth Edition*, John Wiley & Sons, Inc., New York, NY, 2000.
2. Amos, Scott J., editor, *Skills and Knowledge of Cost Engineering, 5th Ed. Rev.*, Chapter 13: Scheduling, AACE International, Morgantown, WV, 2007.
3. Fondahl, John W. *The Development of the Construction Engineer: Past Progress and Future Progress*, Journal of Construction Engineering and Management, Vol. 117, No. 3, Pp. 380-392, ASCE, Reston, VA, September 1991.
4. O'Brien, James J, and Fredric L. Plotnick, *CPM in Construction Management, Sixth Edition*, McGraw-Hill Companies, Inc., New York, NY, 2006.
5. *Primavera Project Planner Reference Manual, Version 3.0*, Primavera Systems, Inc., Bala Cynwyd, PA. (Longest path was introduced in P3 for Windows Version 2.0b and is now implemented in SureTrak as well as the Primavera Enterprise software.)
6. Winter, Ronald M., *Longest Path Value (to the Rescue)*, 2004 Primavera Annual Conference Proceedings, Primavera Systems, Inc., Bala Cynwyd, PA, 2004.
7. Hoshino, Kenji P., *Catching the Elusive As-Built Critical Path*, 2002 AACE International Transactions, AACE International, Morgantown, WV, 2002.
8. Winter, Ronald M., *Longest Path Software*, Ron Winter Consulting LLC, [www.ronwinterconsulting.com](http://www.ronwinterconsulting.com), 2003
9. Herold, Scott C., *Enhanced PDM*, Proceedings of the PMI College of Scheduling 2004 Annual Meeting, PMI, Newtown Square, PA, 2004.
10. AACE International, Recommended Practice No. 10S-90, *Cost Engineering Terminology*, AACE International, Morgantown, WV, (latest revision).
11. Calvey, Timothy T., and Ronald M. Winter, *Probabilistic Delay Analysis*, Proceedings of the PMI College of Scheduling 2007 Annual Meeting, PMI, Newtown Square, PA, 2007.
12. Kim, Kyunghwan and Jesus de la Garza, *Phantom Float*, Journal of Construction Engineering and Management, Vol. 129, No. 5, Pp. 507-517, ASCE, Reston, VA, October 2003.

13. Hollmann, John K., Editor, *Total Cost Management Framework: An Integrated Approach to Portfolio, Program, and Project Management*, (Chapter 7.2 Schedule Planning and Development), AACE International, Morgantown WV, 2006.

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