Managing Multiple Milestones
Copyright 2004 by Ron Winter, PSP
Ron Winter Consulting LLC
13NOV04

ABSTRACT

This article is a 'must-read' for any Scheduler who has ever had to manage a schedule with multiple contractual milestones. An original technique is offered by the Author that should be in all professional Scheduler's 'toolboxes.'

The problem of using a single float value to manage a project with multiple contractual milestones has challenged the best of Schedulers. This paper revisits the issue by taking an entirely new approach to the problem using longest path.

A known expert in the use of longest path explains how longest path is the only correct method for determining milestone-controlling activities. The author then proceeds to explain an entirely new way to create Milestone Longest Paths for this crucial measurement using a simple procedure available to everyone. Finally, we list the first-ever, "rules for the proper use of longest path."

MILESTONES

Milestones are points in time that mark special events. In CPM schedules, milestones are zero-duration activities that are sometimes used to mark formal completion of the construction of specific phases or work areas. Events such as "Establish Permanent Power" may be useful to allow for the testing of elevators as well as for the timing of additional owner-based issues. Milestones can also be used as a method of controlling and managing a complex project.

Projects with a single completion milestone are difficult for the Owner to manage. When informed by the Owner that they are behind schedule, Contractors sometimes just reply that they intend to catch-up later. The owner usually lacks a mechanism for preventing late completion of their project. In their textbook, "CPM in Construction Management" by O'Brien and Plotnick [1], they recommend the use of contractual interim milestones for controlling some projects.

O'Brien and Plotnick state that by establishing contractual interim milestones at key project milestones, the owner can encourage the contractor to keep on-schedule throughout the project instead of hoping for the miracle at the end. The Authors state, "Establishing milestones as a contractual requirement helps the owner to control the project's progress, and it provides a definite area to control the performance of the contractor." O'Brien and Plotnick further recommend, "One answer is to lock in the contract dates to the milestones so that when a project is behind schedule it will exhibit negative float."

When you calculate the CPM on a schedule with multiple milestones and 'locked-in dates,' you will most likely see that the milestones have a wide range of float values. When the float of every activity in the schedule is positive or zero, you can 'rest easy' in the knowledge that you are on-time. But what if some of the milestones have positive float and others have negative float? What if you need to accelerate the project for one milestone and not necessarily to accelerate all of them?

This is not just a problem for Owners, but for Contractors as well. Each milestone may have a different liquidated damages value assigned to it. How does the Contractor best employ his limited resources to minimize the late costs? Further mitigation efforts may resolve the delay to the final milestones, but what work is directly responsible for delaying the upcoming milestones? Looking to the float values does not solve this issue.

What is missing here is a scheduling mechanism to manage the program to meet the milestones. There is only one total float value for every activity and there may be many milestones, each on separate paths throughout the schedule. How can one number be used to indicate the contribution of each activity to each of the individual milestones?

How do you identify the activities responsible for controlling the early start timing for a milestone? Activities with negative float may not have anything to do with the timing of any given milestone. Without being able to identify the critical activities leading to the target milestone, how can you control your milestone?

In the well-respected textbook, "Construction Project Management," by Clough, Sears and Sears [2] the authors discuss milestones and procedures for accelerating them. On page 155 the authors state, "The longest path from project start to that event determines the early time for any event, and efforts to advance the event time must be concerned with shortening this longest path."

It seems clear that the correct method for managing milestones is to manage the activities on the longest path leading to that particular milestone. This plan agrees with classical CPM theory. Unfortunately, current software does not provide you with this information. Let us look at how the leading construction scheduling software, P3 [3] looks at calculating the longest path.

P3 LONGEST PATH

Primavera Systems, Inc., the makers of Primavera Project Planner (P3) scheduling software defines 'Longest Path' as, "*P3 calculates the longest path by identifying the activities that have an early finish equal to the latest calculated early finish for the project. P3 identifies all driving relationships for these activities and traces them back to the project start date.* " [4]. In Figure 1, the longest path would finish with the milestone labeled, "Project Completion Milestone" and is represented in bold activity boxes.
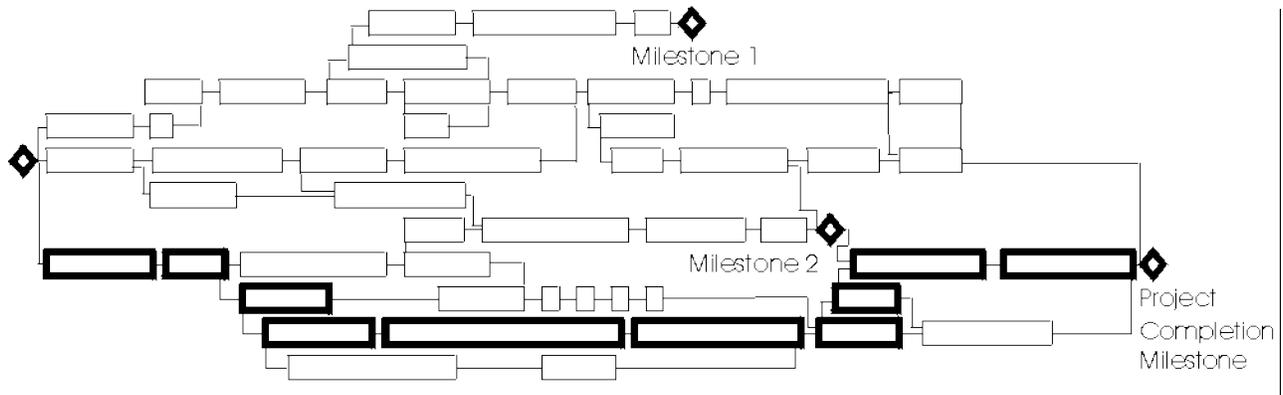
Figure 1, A Typical Schedule

P3 calculates the longest path by finding the last activity in the network and then tracing all of the driving relationships back to the project start date. P3 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*." If you have used P3, then you have seen the asterisk ("*") in the predecessor or successor window denoting the fact that a particular relationship was a driving relationship.

Just like the CPM, the Longest Path is a process. It finds the last activity in the schedule. It then travels backward through the schedule using the driving relationships to identify all activities that are related to the last activity via driving relationships. This list comprises the Longest Path.

THE PROBLEM WITH P3 LONGEST PATH

What do you do if your milestone does not fall on the calculated longest path? Even your Project Completion milestone is not guaranteed to fall on the longest path. The last activity in the project is not always part of the required work for Substantial Completion. What if the last activity is "Landscape Maintenance" and this activity started well before the Substantial Completion? Your computed longest path will not include your final milestone. .See Figure 2 for just such an example where the Project Completion Milestone is not on the longest path. The new longest path is shown in bold.
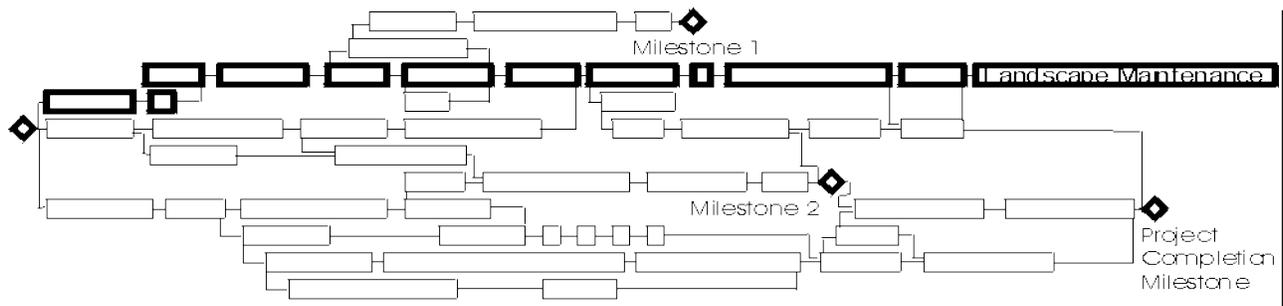

Figure 2, Project Completion not on the Longest Path

Even if the last milestone is included in your longest path, the odds are great that other interim milestones will not be. How do you determine the longest path to each milestone? How can you control a project when you do not even know what work is pushing the completion of a milestone?

THE SOLUTION

What we want is to make the longest path go through any given milestone and then to note which predecessors to that milestone were also on the longest path. This will define for us the controlling work for that particular milestone. If we then switch the schedule so that we can make the longest path to go through the next milestone, then we can identify the controlling activities for that milestone and so on until we have analyzed all milestones on the project.

The 'secret' to the procedure of controlling which milestone lies on the longest path is by determining the activity with the latest finish in the project. Remember the procedure that P3 uses to compute the longest path; it begins with the activity with the latest early finish and then works backward, tracing the driving relationships.

The solution to this problem lies in being able to treat a particular milestone as if it were the last activity in the project and then calculate the CPM and the longest path. The rest of the schedule may not give expected results, but we do not care about this as we are going to set everything right again after we are done.

How do we make any given milestone activity act as if it were the last activity in the network? We 'cheat' and add a temporary activity as an immediate successor to the milestone. This temporary activity will be given a duration such that its early finish is latter than the project's early finish. This will temporarily 'throw-off' the rest of the network, but it is only temporary and will be removed when we are done.

So we add a new activity to the schedule, called "Temporary Longest Path" and assign it as a successor of the milestone activity we wish to analyze.   We then assign it an Expected Finish constraint of 10 days later than the current early project completion date. If the early project completion date was 12AUG05, then we assign the Expected Finish constraint to be 22AUG05. Figure 3 depicts an example of this process. We run the CPM and then run a report for the longest path, excluding your Temporary Longest Path activity. The listing of the activities shown in bold will be in your "Milestone 1 Longest Path Report."
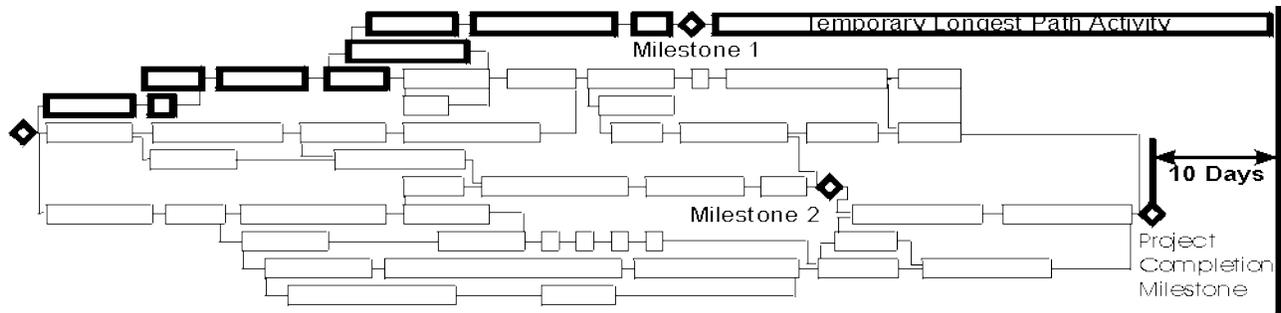
Figure 3, Add Temp Longest Path Activity to Milestone 1

We switch the predecessor for the Temporary Longest Path activity from the first milestone to the next milestone to be analyzed (Milestone 2 as shown in Figure 4 below) and re-run the CPM. We re-run the same Milestone Longest Path Report and label this one for the Milestone 2. Notice how the bold activity boxes indicate a different longest path for Milestone 2 than obtained from Milestone 1.
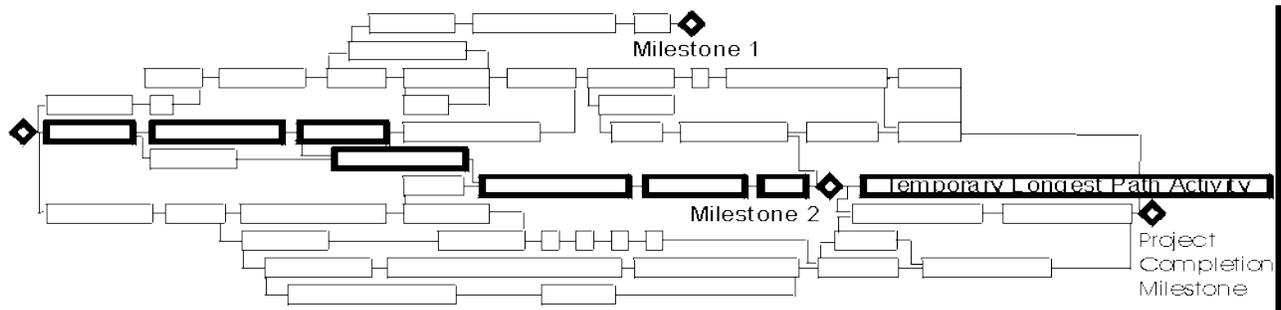
Figure 4 – Switch Temp Longest Path Activity to Milestone 2

We continue this procedure of moving the Temporary Longest Path activity and re-running the CPM calculation until we have analyzed all milestones. Now we delete the Temporary Longest Path activity and re-run the CPM to return our schedule back to normal.

INTERPRETING THE RESULTS

When we are complete with our milestone analysis, we will have several lists of activities. Each list will contain all of the activities on the longest path leading up to a particular milestone. The various lists may or may not include the same activities. The activities listed will be the ones that are determining the early start of that particular milestone.

How does this help us? According to the rules of CPM, reducing the duration of any activity on this list will accelerate the completion of that particular milestone. This is how you can control and monitor any specific milestone; by controlling and monitoring the activities on the longest path leading to that milestone.

Of course, you cannot reduce the durations of the activities on the longest path indefinitely without creating an alternate longest path. This is due to the dynamic nature of a CPM schedule. It will require a little trial and error to determine just how much reduction is achievable and at what cost before you will have your acceleration plan completely worked-out.

DANGERS IN USING LONGEST PATH

Very little has been written on the actual use of longest path and the pitfalls from misuse of this technique. The only paper know to this author was written (by this author) in 2002 [6]. There are four distinct cases where the use of longest path can be misleading and give incorrect results; Substantial Completion, CPM calculation mode, variable duration activities, and the use of constraints.

<u>Substantial Completion</u>

We have already discussed this issue earlier. Call it "Substantial Completion," "Project Completion," or "What-have-you"; the longest path is only representative of the remaining work if that work actually includes the point in the project where the project is officially over. The P3 implementation of this feature does not consider this fact, so you need to make sure of it on your own. Considering our example above, no one is interested in knowing the work necessary to make Landscape Maintenance happen (other than the Landscaper.)

<u>CPM Calculation Mode</u>

P3 allows for two different methods for computing the CPM in the case of out-of-sequence progress. The first method, called "Retained Logic" assumes that you may have started an activity earlier than logic dictates, but that you must suspend all planned progress on that activity until the predecessor activities are complete. The other method is called, "Progress Override" and assumes that once an activity has started out-of-sequence, that you may expect it to be able to continue progressing normally,

Most CPM experts recommend that you use the Retained Logic mode. This is the correct mode to use when using longest path to determine your milestone controlling work. Progress Override acts as if the original predecessor logic were not there; cutting the predecessor activities out of the longest path.

We will illustrate our point with a hypothetical example.   Figure 5 below shows two sets of a series of five activities that are on the longest path. The top set of activities is all without progress. With the Progress Override CPM setting, statusing Activity C as having started will cause Activities A & B to 'drop off' the longest path, as shown in the bottom set. Once Activity C starts, Activities A and B are no longer critical.
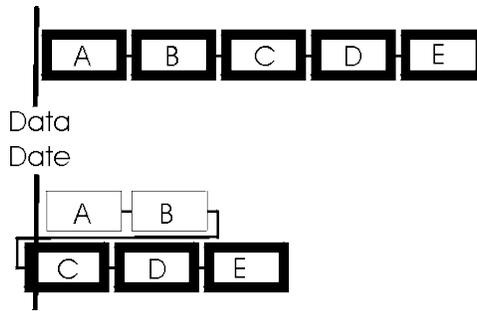
Figure 5, Progress Override Example

Before the out-of-sequence activity started, the predecessor was on the longest path and now it no longer is. If the predecessor activity was controlling before, how can out-of-sequence work remove that activity from the longest path? This is clearly illogical.

Variable Duration Activities

P3 also has another CPM calculation rule called "Continuous" or "Interruptible" Activities. If an activity is constrained by logic at both its start and finish, and if the constraints do not match, then a conflict exists. Either the start must slip or the activity's duration must elongate.

The Continuous CPM setting states that in the event of a conflict, the finish constraint will take precedence and the start of the activity will be delayed to match the duration and finish of that activity. This is the correct setting to use when measuring the longest path.

The Interruptible CPM setting states that an activity can start when it is able to and finish when it must. The duration of the activity with logical restraints at each end will automatically expand to accommodate the conflict.

To demonstrate why the Continuous setting should be used, refer to Figure 6 below. In it there are two distinct paths of work, one with 0 days of float and the other with 70 days of float. When the CPM mode is set to the Interruptible setting, the activity marked Interruptible Activity increases in duration to match both logical constraints. The float calculation remains the same but the longest path does not.
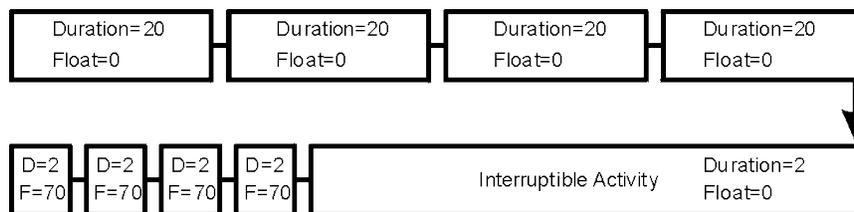

Figure 6, Interruptible Activity Example

With the Continuous CPM setting the longest path of the example below only consists of the upper path of activities with 0 float. With the Interruptible CPM setting, all activities shown in the figure above are included as part of the longest path. Clearly, it is incorrect to consider the activities with 70 days of float to be on the longest path.

Activity Constraints

Total Float considers all activity constraints into the calculation of a float value. This accounts for how float can be negative or how a critical path could begin in the middle of a project with no critical activities for several months.

The P3 implementation of longest path also considers <u>some</u> of the activity constraints. As there is no 'backward pass' in the longest path calculation, it does not consider late constraints that affect this backward pass calculation. In summary, the P3 implementation of the longest path only considers some of the activity constraints; those that affect the forward pass.

Now why should a process like longest path consider some of the constraints and not the others? This leads to the same unacceptable condition that you get using float; namely that in certain cases the longest path begins in the middle of the project. Where is the logic in stating that the controlling work does not exist for a period and then suddenly begins some months in the future?

Figure 7 below shows what can happen to the longest path when constraints are applied. Notice that the bold activity boxes denoting the longest path begin well after the start of the project. Instead, the longest path begins at the place where the early start constraint was applied.
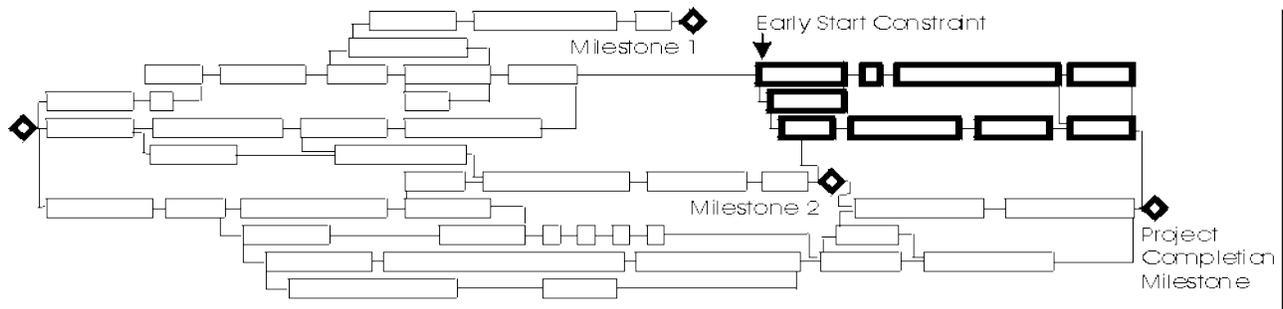

Figure 7, Early Start Constraint and the Longest Path

Clearly, for longest path to be meaningful, it must exclude the use of constraints in its determination. Remember, the definition for the longest path in the P3 manual states, "*the string of directly related activities that comprise the longest path from the data date to the last activity in the schedule*." It is obvious that the above example defies even the P3 definition of longest path.

A BETTER SOLUTION

The above technique was developed after researching the capabilities of a specialty add-on software to P3 called Longest Path Software [5] produced by this author. This package is designed to extend the capabilities of P3's longest path to compute the Longest Path Value for every activity in the schedule, not just for those on the longest path.

The concept of Longest Path Value was first presented to the AACEi [6] at their annual conference in 2003. It has subsequently been presented at the PMI CoS at their first National Convention in 2004 [7] and at the Primavera User's Conference in 2004 [8]. This software also has the ability to allow you to designate the Substantial Completion activity and find the longest path to that activity.

There is a better solution to managing milestones than using the above technique. Longest Path Software can also tell you the longest path to each of your milestones using a built-in feature. Just run Longest Path Software and designate your milestone as the Substantial Completion activity.   This program is designed to ensure that the longest path goes through Substantial Completion by specifically designating the selected activity.

The program will insert the calculated values into your schedule to use at your leisure. Re-run Longest Path Software again to designate the next milestone and note the outcome. No additional activities are inserted into your schedule, so there is nothing to remove after your analysis is complete. In addition, you will not only identify the Milestone Longest Paths, you will also be able to designate the second and third closest Milestone Longest Paths.

This software also automatically enforces the rules that I have listed here for the proper use of longest path. Even if the schedule currently is in violation of any of these rules, the software will automatically correct for this in its calculations.

SUMMARY

Up to now, Schedulers and managers have been hard-pressed to manage and control the timing of milestones in multiple-milestone projects. This lack becomes critical when liquidated damages are applied to each milestone. A system of determination of the controlling work leading to each milestone is absolutely necessary in order to maintain control of costs and contractual obligations.

This paper has introduced a new, previously unpublished method for using the schedule to make this important determination. We have presented two methods, a manual one and an automated one to meet this need. Either method proposed; either by manually adding in a Temporary Termination Activity or by using the Longest Path Software will

allow the user to achieve the necessary results. Rules for proper use of computing the longest path ware also presented to provide professional, consistent results.

[1] "CPM in Construction Management" fifth edition by James J. O'Brien and Frederic L. Plotnick, copyright 1999 by The McGraw-Hill Companies, Inc.

[2] "Construction Project Management," fourth edition by Richard H. Clough, Glenn A. Sears, and S. Keoki Sears, Copyright 2000 by John Wiley & Sons, Inc.

[3] P3 is the short name for "Primavera Project Planner" by Primavera Systems, Inc.

[4] Primavera. Primavera Project Planner Reference Manual, Version 3.0. Primavera Systems, Inc., Three Bala Plaza West, Bala Cynwyd, Pennsylvania.

[5] Longest Path Software, part of Schedule Analyzer by Ron Winter Consulting LLC, Copyright 2002.

[6] AACEI, The Association for the Advancement of Cost Engineering, International. 47th Annual Conference, Orlando FL, www.AACEi.org.

[7] PMI CoS, Project Management Institute College of Scheduling First Annual Conference, Montreal, Canada. www.PMICOS.org

[8] Primavera 21st Annual Convention, New Orleans, LA 2004, www.Primavera.com