The Next Generation

Fredric L. Plotnick, Ph.D., Esq., P.E., is an authority on CPM planning and scheduling and on legal aspects of engineering and construction. Dr. Plotnick, the co-author of two textbooks on CPM scheduling, has also created the Construction CPM Conference, with its fifth annual meeting set for January 12-17 in San Diego. The Next Generation blog discusses CPM scheduling, engineering law and other aspects of project management.

"You Can't Always Get What You Want ..." PROBABILITY OF COMPLETION ON TIME

Posted by fplotnick at 9/17/2009 1:55 PM CDT

Please don't ask me to tell you what I will be doing next week. I am not quite sure what I am doing right now. However, I can tell you, to the day and hour when our three year, $100-million project will be complete.

One of the advantages that CPM (Critical Path Method planning and scheduling) provides the project manager is the ability to calculate (and recalculate as Change so often occurs) a schedule of when tasks are to performed some time in the future, leading to a definitive expectation of a completion date. At least that is what we were taught in the software tutorial. But the real truth is somewhat more complex.

Network logic calculations involve a field of mathematics called merge bias wherever two or more paths of the logic network meet. As a result, normal rules of statistics and averaging are not applied in standard CPM analysis. This was well known (and written about) by the original developers of CPM and its cousin, PERT (Project Evaluation Review Technique, developed by U.S. Navy for its Polaris Missile program shortly after the development of CPM). The developers of CPM and PERT both understood that individual activity durations are estimates and have a known degree of error. Both understood that (subject to systemic errors in estimating) these errors tend to cancel each other out to a large degree. Both also understood the same is not true when solving CPM calculations. But these mathematicians also knew the computers of the 1950s could not solve these types of problems.

Therefore, the developers of CPM used a "fudge factor" – they suggested that the completion date of the CPM was overly optimistic and required a contingency. To quote James J. O'Brien, in his original edition of his classic text, CPM in Construction Management (1965, McGraw-Hill):

> There is a definite tendency for the actual completion date to exceed the first CPM end date. It is, then, reasonable to allow for some contingency between the CPM end and the actual desired completion dates. There is no definite answer on how much contingency to allow for, because it will vary with the specific circumstances of the project. However, if you need a 12-month period for completion of the project, set your CPM goal at about 11 months, and so forth. Some people have been reluctant to set a flat contingency at the end of the schedule. Contingency can be buried in the activity estimates, but if it is, you will not be able to separate true estimates from contingency.

The developers of PERT used a "pseudo-fudge factor," a statistical averaging approach to the tolerances for each activity (or time period between events) using the famous formula of (Optimistic + 4 x Most Likely + Pessimistic)/6. This formula approximates a normal distribution and provides a statistically adjusted solution. While their method is valid when working

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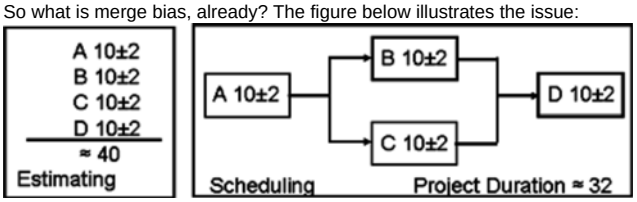
By: acho
5/30/2015 2:10 PM CDT

with a list of numbers, such as a cost estimate, it fails to account for merge bias. Having claimed the mantle of a statistical approach, many practitioners forgot or ignored that the PERT solution still requires the same contingency as CPM. Witness the many government R&D projects that overrun their schedule.

So what is merge bias, already? The figure below illustrates the issue:



The average for a cost estimate with a symmetrical variance is the same as the original total. If each item in the estimate may be high or low by 20%, the total may range from 32 to 48, but the average total will still be 40. For scheduling, this rule does not apply because of merge bias. If each duration may be high or low by 20%, the total may range from 24 to 36, but the average is not 30 (as expected,) instead being 32 (rounded to integer days). Why? 32 is the 'correct' answer because if B is high and C is low, the CPM calculation goes through B; but when B is low and C is high, the calculation goes through C. The calculation goes high 75% of the time and low only 25% of the time. If there are more than two activity paths merging, the merge bias gets larger.

With this in mind, it is understandable that the average project has only a 22% probability of on-time completion. To have a 50% chance of timely completion, a one-year project needs about a month contingency, and so forth, as noted above by Mr. O'Brien. To have a 90% probability of completion, that project needs five to six weeks of contingency.

This is not rocket science. It is more difficult than rocket science. After all, rocket science is merely calculus. (Algebra is the basis of ballistics – firing a canon with an initial velocity and calculating where it will land. Rocket science is calculus – a constant thrust adds increasing velocity to a steadily decreasing mass as fuel is burned and expelled). But, the project manager who understands the need for this level of calculation nowadays may obtain the most likely, rather than only the possible project duration, from the computer at the touch of a button.

So why does the standard CPM specification call for providing a CPM to meet the project completion date only? Does the specification require submission of a bracing shop drawing that will only provide the theoretical strength needed without a factor of safety? Why shouldn't the CPM specification call for provision of a CPM with an 80% or 90% probability of timely completion?

Perhaps until recently, computer hardware and software could not provide that more complex calculation in an economical format. But software products released in recent years do provide this capability. Examples include Oracle Risk Analysis (previously named Primavera Pertmaster), Deltek Open Plan, and a number of add-on programs such as Risk+, Monte Carlo, and others. The primary reason a contractor should prepare a CPM schedule is better to manage the project for a timely completion. The primary reason an owner should ask for a CPM submittal is to provide further assurances of timely completion. Perhaps it is time for owners to ask for what they want and contractors to provide more accurate schedules calculated from their plans.

What's in ***your*** specification?

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Tags: ABCD, CPM, risk, construction, scheduling, specifications, on-time, Plotnick

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Anonymous wrote:

Fred:
I'd like your views on the use of Fuzzy Set theory to increase the accuracy of schedule predictions. I've used Monte Carlo for estimating and scheduling but recently I had an epiphany re. the application of chance or probability to estimating and scheduling. To me probability is "what is my chance of making it through that red light?", but not "what is my chance of completing activity X in < 10 days?" nor "what is the chance of erecting the steel for < 12 mhrs/ton." Fuzzy Set theory asks "what is the possibility of completing activity X in < 10 days?" Prior to

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By: johng555
5/28/2015 2:06 PM CDT

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5/28/2015 11:23 AM CDT

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studying the concept of Fuzzy Set "probability" and "possibility" were synonymous. My recent research, though, leads me to believe there is really something to it. I recognize our industry may not be ready for Fuzzy Set Theory when it is difficult enough to get our practitioners to think at all!

Thoughts?

James Johnson
Heery International, Inc.
Atlanta, GA.
9/18/2009 9:00 AM CDT

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Anonymous wrote:

It was Interesting reading. I agree that a safety factor should be built into a CPM schedule, and that the safety factor time be at the very end of the schedule until needed. If it is distributed in the durations throughout the schedule, it will certainly be used up whether it is required or not. I have noticed a lot of emphasis lately on fuzzy logic or probability. Probability formulas are good for looking at events over which you have no control of the outcomes, such as the roll of the dice, or predicting weather. But on a construction job a good superintendent will influence the durations of activities. It is not chance. A good superintendent will make things happen. If it looks like the rate of progress is not good enough, he will add more manpower. If a subcontractor falls behind, he is asked to make up the time, or will be required to pay for the overtime of others to make up the time. The key is to have good people making sure things are happening per the CPM schedule.
9/18/2009 1:53 PM CDT

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Anonymous wrote:

A well founded explanation from a well respected professional, well done Fred.

Nolan Stewbroth
Bulletproofcontractor.com
9/18/2009 2:27 PM CDT

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Anonymous wrote:

Isn't that what happened to all the mortgages?
9/18/2009 6:17 PM CDT

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Anonymous wrote:

Fred, you are right on track. CPM's prepared and presented without proper risk analaysis is a recipe for a dissappointed owner. Three point estimates and good software make it entirely possible and relatively easy to prepare a schedule where the completion date is assigned a probability or can be presented as a range of dates which is much more realistic.

Mike Stone, PMP, PSP
Richmond, Texas
9/21/2009 6:52 AM CDT

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Anonymous wrote:

You have appropriately addressed the reality of both cost and schedule results. They tend to be skewed to the high side, because if all goes well it can result only a little better than the expected value. However, when things go badly the overrun can be much more severe.
In construction environments where contractors repeat similar activities from project to project the accounting or project control systems have the potential to document these realities. Monte Carlo Simulation can then be applied to past results to reveal the true expected results.
This documentation needs to include calculations for items such as, manhours, man days, crew hours, resource identifiers, etc. to eliminate distortions related to escalation or geographic locations.
Your point is certainly valid and the solution may be right in front of us and remains invisible to the profession.
9/21/2009 8:45 AM CDT

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Anonymous wrote:

Here is the future of CPM:

http://www.associatedcontent.com/article/1259207/is_bruce_bueno_de_mesquita_the_new.html?cat=4

by:
http://www.suretyinsider.com/surety-consultants.html
9/21/2009 9:13 AM CDT

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Anonymous wrote:

Fred,
OR mathematics aside, I wonder whether the dominant reason for unmet schedules is the failure on the part of many CM's to understand that the real value of a Critical Path (or any other type of) schedule is as a PLANNING TOOL. The schedule should not be used as a forecast at the beginning of a project, and then regularly updated with actual durations and changes. It must be used as a MANAGEMENT TOOL, to make needed corrections so that the project CAN be finished on the date specified.
It occurs to me that one of the more salient problems with CPM is not misunderstanding Merge Bias or probability theory; it is not understanding that it is up to the CM to ACT on the information provided by the schedule to affect the outcome.
Regards,
Dan

9/21/2009 9:24 AM CDT

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Anonymous wrote:

Enuthiasm
Disapointment
Panic
Search for the guilty
Punishment of the innocent
Praise and honors for the non-participants.

CPM never changes.

9/24/2009 5:48 AM CDT

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Anonymous wrote:

The difficulty with multiple parallel paths is that each path may be the longest one. It is rather like predicting how long a horse race will take. The winner has the quickest time, but one of the losers takes the longest. This causes the combined probability distribution to be skewed toward the longer times. It is not nearly as difficult to calculate the probability distribution as it is to get acceptance that multiple parallel activities increases the risk of the project coming in late.

12/20/2009 11:44 AM CST

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