Rectification of CPM Schedules

by Ron Winter, PSP

Abstract

"Rectification" of CPM schedules is a term applied by after-project forensic analysts to 'correct' the schedule so that further investigations may be applied to it. These corrections are intended to ensure that the results of the analysis will yield useful information as to cause and effect of delays.

This correcting of schedules is based on more than just a whim; there are rules as to what should and should not be performed. The 'rules' are not actually an industry standard and have not been formally collected into a body of knowledge. This paper has compiled a list of such issues in the current literature and adds some new ideas as well.

Schedule rectification is not just a tool to be used by forensic analysts. This paper will discuss justifications, guidelines, and some specific examples of rectification techniques that can be employed by Project Schedulers. Static as well as Dynamic Rectification issues are discussed to increase the usefulness of Schedule Rectification.

Keywords: Rectification, CPM, Schedules, Static Rectification, Dynamic Rectification

What is Rectification of CPM Schedules?

Schedules using Critical Path Method (CPM) have numerous uses on a project. These 'uses' include the listing all of the work to be performed, to define the timing of that work, and describing the logical relationships between the various pieces of work. When delays or other unexpected events cause the project to deviate from the scheduled dates, we can use the CPM network to demonstrate what happened and to predict the logical results of the change.

The ability of a CPM to model and predict the outcome of actual changes is based upon

- the completeness of modeling the entire work to be performed,
- the accuracy of the network logic in describing and modeling the major inter-relationships and dependencies of the different work units, as well as
- the accuracy of the status.

If some of the work is missing, or the logic, or status is flawed, then this must first be corrected before the results of the CPM computations can be relied upon for measurement. This correction process is sometimes referred to rectifying the schedule.

The word, "Rectify" is defined[1] as follows,

> **rec-ti-fy**: To set right; correct. To correct by calculation or adjustment.

We rectify schedules to,

- eliminate confusion and ambiguity,
- streamline the process of analysis,
- cause the schedule to give reliable and useable results,
- be able to tell a consistent 'story' over the lifetime of the project, and
- correlate project status with the date which the status was taken.

Other terms that mean much the same as 'rectify' include the terms "normalize" and "source validation," as in Source Validation Protocols (SVP.)

Legitimacy of Rectifying Schedules

It is reasonable to first consider whether Schedule Rectification is permissible. If the contractually-required schedule submittal is the "property" of the Contractor and the Contractor is responsible for the accuracy of the schedule, then why should the Owner's Scheduling Representative (Scheduler) be concerned with Schedule Rectification? The Project Schedule may be considered a depiction of Contractor's means and methods. The contractor has the right to choose those means and methods, and so also has the right to modify the Project Schedule.

Certainly, the Contractor's Scheduler (Contractor) should do their own due diligence and make all reasonable effort to correct any errors in the schedule prior to its submittal. This is not the type of 'rectification' that is covered in this paper.

The answer to the question of legitimacy of schedule rectification is that "relevant authority [the courts] makes it clear that a contractor's claim based on a schedule containing erroneous logic or unrealistic durations will be denied." [2]

It is a generally accepted theory that schedule logic problems must be corrected as part of a delay analysis. In "Construction Project Scheduling," [3] the authors state,

> *"A schedule used to prove a delay must be prepared and used as correctly as any other tool necessary for project completion. Thus, before acceptance to measure a delay, the schedule should be demonstrated to be reliable. To be able to use a CPM to measure a delay properly, initial*

data must be sensible, accurate and reasonable. Correct scheduling technique and methodology must have been used, and no open ends are permitted. All activities must be accurately and logically sequenced. If the input was introduced carelessly, or in error, it makes the original schedule incorrect and the analysis of the delay distorted, if based on the incorrect schedule.

"If an original schedule to be used to measure delay or impact has errors, omissions, or other deficiencies, the problems should be corrected. Once revised to eliminate any problems with the schedule, the corrected or revised original schedule can be used to measure delay."

If such a measure should be undertaken as a part of a claims exercise, then why not have the Scheduler perform the same rectification as a part of a Time Impact Analysis to support a Change Order? If that, then why not employ this technique as a part of every schedule update review? Schedule Rectification is a necessary and important tool for Schedulers 'in the field' as well as for Claims Consultants.

Instead of waiting for the project to be complete before performing this process, we should consider training Project Schedulers to also consider rectifying CPM schedule updates as they are submitted. Properly rectifying CPM schedules of errors in the current schedule submittal has a much larger chance of avoiding mistakes at a much lower cost than waiting for "experts" to do this same thing after the project is complete. This clarification to the schedule also raises the schedule's value later in possible dispute resolution due to its contemporary nature**.**

The Other Viewpoint

To be fair and balanced, there are two professionally recognized viewpoints to the legitimacy of rectifying schedules. The majority of forensic analysts believe that schedule rectification is legitimate and necessary when performed fairly and correctly. Another group of analysts feel that only analysis of unaltered schedules is permissible.

TCM Framework 6.4 – Forensic Performance Assessment [5] Section 3.5, "Observational / Dynamic / Modified or Recreated (MIP 3.5)" is by far the most popularly applied technique and describes situations where schedule rectification is considered valid and necessary. On the other hand, Section 3.3, "Observational / Dynamic / Contemporaneous As-Is (MIP 3.3)" has a much smaller practice and can be described as performing analysis without applying any changes.

It seems to me that the reasons forwarded for not rectifying the schedule when performing claims analysis after the project is complete are almost completely addressed by having the Scheduler "on the field" perform the rectification. When rectification techniques are properly applied on contemporaneous schedules while the project is on-going and the schedule can be considered, "current" then these changes can be validated by the project team.

Rectification by Schedulers

The Scheduler who reviews a schedule is charged with being more than just a gateway for schedule submittals; he or she is expected to validate the information and to draw conclusions from valid schedules. Scheduling errors that can be proven to be logically incorrect are reasonable candidates for correction.

Before the Scheduler can draw conclusions, they must be sure that the schedule is valid. This means that we must ensure that any incremental changes made to the schedule since the last valid schedule was submitted are also valid changes.

This paper will look at schedule rectification from a Reviewing Scheduler's viewpoint and not that of a Claims Consultant. In this regard, the Scheduler would most often be the Owner's Representative, receiving a schedule submittal from the Contractor's Representative. The difference between the perspective of a Scheduler working on the actual project and a Claims Consultant evaluating the schedule after project completion can be radically different.

The Claims Consultant is further removed from the actual work but has access to more of the daily project documentation. While the Scheduler in the field has the possibility of actually knowing when activities started and finished, the Consultant looking at the project documentation is better able to prove it and has the time to do so. So who typically validates current schedule dates?

The Claim Consultant is typically the party who validates the dates and the logic reported in the schedule. What this logically means is that in the eyes of a Claims Consultant, the act of a Scheduler not objecting to a reported status date does not give support to the date's accuracy. This is a poor assessment of the current state of the art for scheduling.

Finally, it is easier for a Claims Consultant to rectify schedules. The Claims Consultant does not need to get Contractor 'buy-in' when adjusting a schedule; only that of the judging authority. On the other hand, unilateral changes to the project schedule by the Owner's Representative may easily result in a schism between the Contractor and the Owner, resulting in two versions of the same event and decreased teamwork between the two parties.

Types of Rectification

There are two major approaches to looking at the accuracy of CPM schedules. You can rectify them based upon a single schedule and you can rectify a series of related updates. Let us call this Static and Dynamic Rectification.

Static Schedule Rectification

Correcting a single CPM schedule representing a single data date is called Static Rectification. Correcting a single schedule is the easiest and simplest of schedule analyses. This should be done for every schedule update submittal. If not done, this can easily corrupt any conclusions that may be drawn form the schedule. Specific static conditions that should be considered for rectification include the following,

Improper Actual Dates

Actual dates in the future (later than the data date) can be used to hide the critical path. Figure 1 shows just such an example,

Activity ID	Activity Description	Orig Dur	Rem Dur	Total Float	Actual Start	Actual Finish
100	Act 1	10	0		10DEC08	23DEC08
110	Act 2	5	5	5		
120	Act 3	15	10	0	12DEC08	

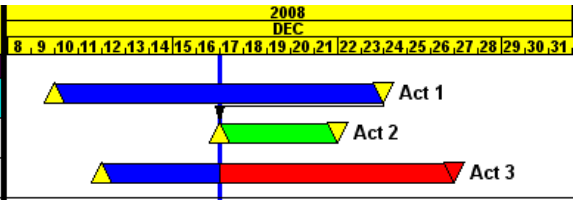

Figure 1 – Actual Date in the Future

Figure 2 shows the result of rectifying this 'error'. The activity has been returned to uncompleted status and the proper remaining duration has been added to make the early finish of the activity equal to the stated actual finish date. Nothing has changed; Act 1 still finishes on 23DEC08.

Activity ID	Activity Description	Orig Dur	Rem Dur	Total Float	Actual Start	Actual Finish
100	Act 1	10	7	0	10DEC08	
110	Act 2	5	5	0		
120	Act 3	15	10	2	12DEC08	

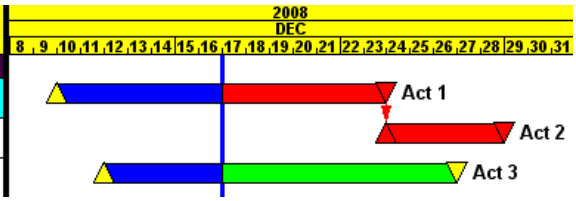

Figure 2 – Actual Date replaced with an Early Finish

Note how the critical path shifts because of this 'benign' change. Clearly, actual dates in the future can be used to hide the criticality of that activity and the ones that follow it. It is also important to note that the condition noted in Figure 1 occurs when using the CPM calculation mode of Retained Logic as well as under Progress Override.

Uncompleted Work prior to the Status Date

Uncompleted work in the past hides the fact that this work must still be performed in the future. Figure 3 illustrates this condition. Primavera software will not allow this condition to exist but MS Project 'suffers' from this weakness.

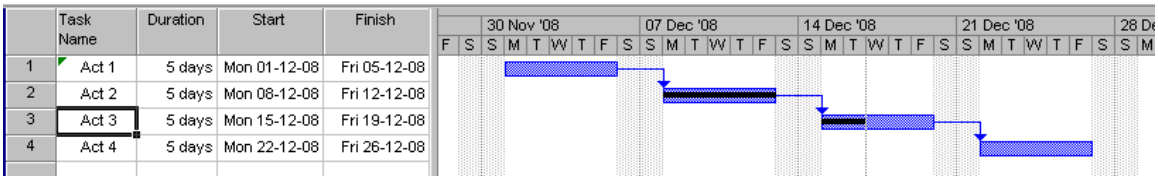

Figure 3 – Uncompleted Work in the Past

Even though the CPM indicates that we are on track for timely completion, as of 16DEC08, it does not account for the uncompleted work (and the requisite time necessary to perform such work) shown in Act 1.

Out-of-Sequence Progress

Out-of-sequence progress can be used along with the CPM calculation mode, "Progress Override" to remove activities from the critical path and make the predicted project completion date appear to occur earlier.

I once knew a Contractor who 'overcame' a month's worth of delay by putting out a barrier for a critical lane closure not planned to be executed for another month and statusing the activity as 1% complete. Under Progress Override, all of the current critical work was summarily dismissed as having many months of float and the projected project completion date was brought back to indicate that the project was once again on-time. Figure 4 illustrates a simplified version of this scenario.

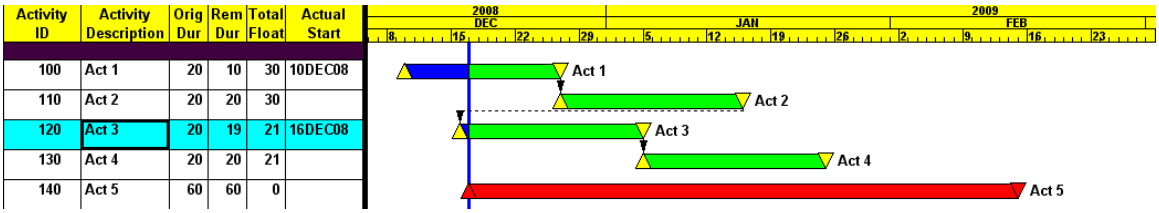

Figure 4 – Out-of-Sequence Progress with Progress Override

A simple rectification of the schedule CPM calculation rules from Progress Override to Retained Logic produces a dynamic change in the criticality of the outstanding work as show in Figure 5.

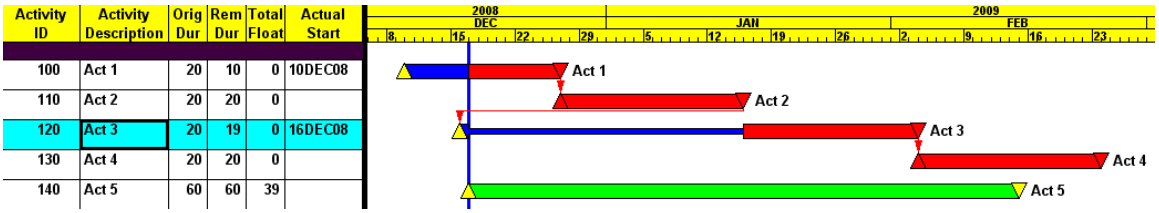

Figure 5 – Out-of-Sequence Progress with Retained Logic

Some would say that the correct course of action is to correct each activity and logic tie to reflect how the project was actually built. While this is a reasonable procedure for gross changes involving a significant portion of the schedule, documenting every deviation from the plan may not be necessary if you are mainly interested in predicting

project completion and displaying overall status. In the example above, the CPM calculation setting of Retained Logic allows for a reasonably accurate depiction for the progress for the limited number of activities involved.

Missing Relationships

It is often not reasonable to include every possible relationship affecting activity sequencing. Normally, the Contractor only includes relationships felt most likely to be involved in determining the timing of successor activities. Later, unusual circumstances may cause logical constraints that were not codified in the original baseline to become significant drivers of the schedule.

If conditions such as this exist that are affecting near-critical (or thought to be important) work, it is necessary to identify and document the missing relationship constraint. The Contractor should add the relationship to the schedule and the Scheduler should weight the reasonableness of the addition. It is best if both parties should discuss and agree on the correct change to be made. Failure to do so only leads the schedule open for later interpretation based upon a poorer understanding of the current situation and possibly a less objective rectification.

Constraints

The use of constraints in schedule update is a very controversial subject. While the Contractor has the right to plan the timing of his work, this does not mean that he is allowed to sequester the available project float for his or her sole use. Constraints are sometimes purposefully or inadvertently used for this purpose.

For analysis purposes, it is permissible to remove unnecessary constraints. Unnecessary constraints fall into the following categories,

- Redundant, project-wide constraints,
- Purely preferential start constraints,
- Purely preferential finish constraints, and
- Float constraints (i.e. Zero Free Float or Zero Total Float.)

As a general rule, constraints should not be the sole source for determining the timing of an activity. Appropriate constraining logic should always be documented as well.

There are occasions where it is appropriate to insert constraints on activities in the schedule. Examples of allowable use of constraints fall into the following categories,

A. Contractual date commitments:

- Project Completion,
- Interim milestones, and
- Joint occupancy dates.

B. Delivery commitments:

- Major components and materials,
- Key construction equipment, and
- Subcontractor mobilization commitments.

C. Third party restrictions:

- Waterway restriction and
- Utility company connection.

D. Just-In-Time scheduling (using Zero Free Float constraints):

- Delivery of damage-prone components.

Calendars

Activity and Resource Calendars often hide or exaggerate important issues that should be considered. Many analysts recommend that you minimize the use of multiple calendars to avoid the problems of gaps when changing from one calendar to another in the same float path. Others find this permissible as it only reflects the physical constraints of the project.

Reviewers should always check the calendars used to confirm that the correct holidays and other non-workdays are reflected in the calendars. Sometimes, modifying an activity's calendar can move that activity on or off of the current critical path. This type of change is very difficult to detect if you do not review the calendars on every schedule update.

Relationship Lags

Relationship lags are used to indicate a timing event between the related activities. Like calendars, changes to the lag can modify an activity's criticality and the effects of this change are very difficult to detect other than by directly reviewing a lag report. Certain lag conditions are very suspect. These anomalous lags include,

- Finish-to-Start (FS) lag larger that the threshold duration used for near-critical,
- Start-to-Start (SS) lag larger than the predecessor duration,
- Finish-to-Finish (FF) lag larger than the successor duration,
- Start-to-Finish (SF) lag larger than the successor & predecessor durations combined, and
- FS negative lag whose absolute value is greater than the predecessor duration.[4]

With the exception of a Finish-to-Start relationship with a positive lag, a general rule for lag acceptability is that lags should overlap the activity period of at least one of the two activities involved without gaps.

Dynamic Schedule Rectification

Much of today's forensic analysis documentation pertains to the analysis of a single schedule. Since the courts recognize the importance of the dynamic nature of CPM schedules, shouldn't we do more than just analyze single schedules? Shouldn't we analyze the changes made to schedules over time? We call this Dynamic Schedule Rectification.

There are some logical errors or anomalies that can only be discovered by looking at the time period referenced during a status update. Even though a schedule update contains the status of the project from its beginning to the current data date, only the status for the time period from the prior schedule update to this one should reflect changes. Status conditions prior to the last schedule update's data date should not be modified without explanation

Of course, there are exceptions. When validating schedules, it is important to discount corrections made in the subsequent update. This may be just the contractor correcting an earlier mistake. You do not want to fault the Contractor for complying with your earlier request to make a correction to the schedule.

The following issues in themselves are not necessarily incorrect unless you take a longer viewpoint and compare them against what was documented in earlier schedules. Certainly current project records other than the schedule should also be consulted to validate your findings.

<u>Altered CPM Calculation Settings</u>

CPM calculation settings should not change from update to update. These are the "rules of the game" and changing a rule implies

1. that there is a valid reason for the change and
2. that this change applies equally well for every other activity in the schedule. It is better to change the logic or activity definitions for a few activities than it is to change the CPM rules for all activities to correct one isolated situation.

Once the CPM calculation rules have been changed, it is difficult to make historical comparisons of status created under a different set of rules. If such a change to the settings must be made, consideration should be made to reviewing and documenting what the earlier schedules would have looked like had the change been made at the start of the project.

Changing Activity Definitions

Sometimes activities are added or deleted from one schedule update to the next. This may legitimately be the result in reflecting new Change Orders, documenting unexpected events, or noting changes to the work plan. These changes should only reflect modifications to the project that occurred in the immediate update period and not in update periods earlier than the current one.

Adding or deleting historical activities (ones completed earlier than the last status update) possibly invalidates the status of previously reviewed schedules. This has the potential of retroactively causing previous schedule submittals to be rejected for their newly-realized inaccuracy.

Activity IDs should never be changed. Even previously deleted activities should not have their Activity IDs 'recycled' and used for new activities. This practice confuses later analysis and draws a question of whether the actual planned work was redefined as well.

Even activity descriptions should not be modified over time. This also causes questions as to the redefinition of the planned work, possibly deleting some of the scope or quality of the work to be performed. This admonishment also pertains to sub-activities such as Primavera P6 Steps.

Finally if activities are deleted or modified, then you should make sure that all of the originally documented work and budgets, etc. are distributed to other activities in the schedule so as to preserve the original whole plan of work. Ideally, the redistributed work should be documented in a new activity.

Modified Actual Dates

As a Scheduler, I have frequently seen actual dates from prior schedule submittals being deleted or modified in later schedule updates. Perhaps to the Contractor uncovered a previous mistake while updating the current schedule? Maybe they thought that a particular activity was complete but later realized that they mis-understood the planned scope of the work or had mistaken one task for another.

What do you do if you had one set of actual dates and then notice that the Contractor has changed those actual dates in a later update? The best course of action is to independently verify the correct dates. Unfortunately, quite often this is difficult or impossible for a Scheduler without access to the Contractor's field logs to do.

I have asked this question of many analysts who initially felt that the Contractor may have changed the correct date to an incorrect one in order to prove some point of view. I have found that the last actual date modification is the correct one. Contractors typically discover that they made a statusing error when they later go to status some activity as complete and see that it had already been statused complete some time earlier.

There is no clear-cut rectification 'rule' that can be followed in the case of modified actual dates. The only suggestion that I can make is that the party making the change should acknowledge each change in writing with the reason for the change. The absolute minimum a Scheduler should accept is a clear, written statement from the Contractor that the change was or was not made on purpose. We don't want a situation to later arise where either date is the 'official' date, depending upon which one works-out best. Sometimes, the best that a Scheduler can do is to eliminate ambiguity.

Uneven Activity Progress

What if your schedule indicates that the Contractor showed no progress for an activity one month and then later shows two month's of progress in the next update? It is possible that this could have occurred just the way it was reported but the reviewer should look further into this issue. It is more probable that the Contractor neglected to update the status on that activity the first month.

What if that same activity with uneven progress was critical according to the previous update and the source of a delay caused by the Owner? Is it possible that the delayed activity would not have been project critical if some of that two month's worth of progress were attributable earlier? Obviously this sort of anomaly merits further investigation. The Scheduler on the project is in the perfect position to make that investigation.

Changes in Network Logic

Logic changes made during a schedule update may be just the result of documenting the actual work sequence (creating an 'As-Built' schedule) or it could be a plan change. But what do you do if a relationship that executed during the last update period was modified but it was updated in a way that did not occur?

Not every relationship in a schedule is usually verified and updated for accuracy during the course of a project, so it is not typically noted as an error if it were not changed. On the other hand, if a purposeful change was made to the logic, then this change must match with reality. You cannot change the logic to say that an activity must be complete before the other can start if the successor has already started and the predecessor has not finished. In that particular situation, you have changed your logic in contradiction to your reported status.

Any change in logic that is clearly contradicted by actual status should be reversed to the original state. You may legitimately elect to not update the As-Built status of a relationship but a purposeful change must be a correct one. It is not acceptable to update a relationship with something that did not happen.

Another type of change to the logic that should be rectified is a change in the future plan that is later not followed by the Contractor, especially if the original logic was followed instead. This could occur when someone forgot to order a required piece of equipment

on-time and the activity was removed from the critical path, 'preventing' this from becoming a delaying event. If it later proves out that the successor activities were indeed delayed until the missing equipment appeared, then the logic change might well prove to be unjustified and should be returned to the original settings. One smart Scheduler catching this 'trick' on the field is worth a dozen Forensic Experts working after the project is complete.

Expenses / Resources

Individual activity budgets and planned resource totals should remain constant, and should always total to the same amount. If activities are split, then the activity's budget should be likewise properly split. Deleted activities should have their budgets properly distributed into other activities. This re-distribution of resources or budgets should be documented.

Rules for Rectification of Schedules

For the record, there are several formal rules for CPM Schedule Rectification that have been previously been published by noted authorities. While there are many more such rules that can be considered, the following consist of the minimum basic rules that should be referenced.

GENERAL RULES

Fairness to Imperfect Planning

> All plans are imperfect and we should have a balanced approach to the imperfections attributed to the Owner as well as to the Contractor. "If there were no as-planned network or it was inadequate, an as-should-have-been network can be substituted based upon what may be ascertained as the contractor's original plan of execution."
>
> "In the event that the subcontractor's CPM is missing some portion of the scope of work (such as installation of a pipe below the foundation), this is to be treated similarly as when the engineer's drawings are missing an existing condition (such as a buried pipe) or necessary scope of work requiring a change order. In either case, the work additional to the contractor's original plan will be added to the as-impacted network. "[6]

There are two major approaches to looking at the accuracy of CPM schedules, Static and Dynamic Rectification.

STATIC RECTIFICATION RULES

- No uncompleted work shall be scheduled to occur on dates earlier than the current schedule status date.[7]

- No activity shall show progress data for any date on or after the status date.[5]

- Actual Start and Finish status for an activity must be accompanied by a specific date and those dates must be logically consistent with each other and the status date.

DYNAMIC RECTIFICATION RULES

- The actual start and finish dates assigned to each schedule activity must be consistent from update to update.[5]

- The CPM calculation modes and rules (e.g. retained logic, progress override, etc.) of each schedule must be consistent from update to update.[5]

- Modifications to the schedule plan must not be made solely to modify or 'steer' the critical path towards or away from any particular activity. [2]

How and When to Rectify a Schedule

There are some potentially troubling consequences to be considered concerning enforcing Dynamic Rectification. It is easier to object to errors in a single schedule update than it is to justify dynamic schedule objections.

What if you note variations made in one update that possibly invalidates findings made in earlier schedules? What if you spot changes made to historical data? Perhaps you observe logic changes made to the plan that shifted the critical path. What should a Scheduler do in these instances?

Perhaps the Scheduler notes that such change had an advantageous effect for the Contractor on a pending delay extension request. Perhaps later the changed logic was not actually carried-out. What does this mean to completed agreements?

- How does one retroactively revoke the acceptance of a schedule update (or a series of such updates?)
- What is the proper course of action to be followed should a non-current schedule update be retroactively rejected?
- What does this imply about the validity of the current schedule update submittal?
- Should we be considering adjusting already paid compensation?
- How would such an adjustment be carried out?

These are all good questions with very little historical guidance. Perhaps the solution lies in the under-used area of "communication."

For a Scheduler in the field with an on-going project, it is not enough to just rectify schedule submittals; one must also communicate the reason for each change and convince others that the change was needed. If the other side of a contractual agreement objects to the changes, then you are faced with the possibility of having two different schedules documenting the exact same status with possibly two different conclusions to be drawn.

The issue of unilaterally forcing a change to a submitted schedule is one worthy of the Wisdom of King Solomon. Agreement between both parties is very desirable when a change has been made to a schedule by the other party. This reduces wasted effort in maintaining multiple schedules and disagreements as to the current status.

As always, the Project Scheduler must weight what they may lose against what they may gain by making unilateral changes. If the error is minor and has no impact on the critical path or other contract-related issues, then perhaps the rectification of that change should be documented but not insisted upon being implemented. At least then, a later forensic analyst would have ample justification for making the suggested rectification.

On the other hand, if such a change will have a potential effect on the contractual obligations of one party or the other, then it might be a mistake to allow that schedule to become an agreed-upon project document. It is better to not have agreement concerning the progress and forecast of a month's status than to have an agreement that is false and damaging to your client.

Conclusion

Schedule Rectification has been employed by Scheduling Forensic Experts ever since the first CPM schedule was used to demonstrate cause and effect. Rectification of schedules during dispute resolution is a valid, recognized technique.

Rectification of schedule submittals by the Project Scheduler while a project is on-going is much less often performed a formal practice. The financial stakes may be just as high for the Project and the potential for prevention of bad schedule forecasting and improper use in Time Impact Analyses certainly make this a worthwhile formal plan.

The Author

Ron Winter, PSP is an independent CPM Scheduler and Owner of Ron Winter Consulting LLC, the makers of Schedule Analyzer™ Software. He can be reached via the web at Ron@RonWinterConsulting.com

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