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Retrospective TIAs: Time to Lay Them to Rest

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The two principal schools of thought concerning forensic schedule analysis methodology have very different views as to how to identify the as-built critical path and identify delay causing events. This paper will examine these two schools of thought regarding retrospective schedule analysis, including the following.

- methodologies that model real events that have already occurred on the project through computer simulations, represented by time impact analysis methodology; and,
- methodologies that observe the actual events, represented by the as-planned vs. as-built (APAB) methodology.

After nearly two decades of ascendancy of time impact analysis (TIA), culminating in it becoming the legally preferred method for retrospective schedule analysis in the United Kingdom, is it time for the future of forensic schedule delay analysis to return to the past, the as-planned vs. as-built method?

OPENING

There are no fads in the law. Attorneys instead call them "trends." The trend considered in this article is best reflected by a review of recent articles dealing with the "most widely accepted" or "best" forensic schedule delay analysis methodology [1]. These articles would have us believe that the trend in this area is to use retrospective time impact analysis to identify a project's critical path, the party responsible for the delay, and the amount of delay or recovery [2]. For the reasons described in the paragraphs below, I believe this trend (or fad) in thinking should pass, and pass quickly.

Schedule delay analysis, as it existed prior to the widespread use of PCs and portable CPM software, was a time-consuming, laborious, and expensive undertaking. Experts reviewed bar charts of early CPM printouts and compared them to the planned sequence in order to identify the critical path. These as-planned vs. as-built analyses depended almost exclusively on the knowledge and experience of the expert: could he or she explain what happened in a logical and rational manner consistent with the known facts?

With the widespread use of PC-based electronic scheduling software, Primavera and other schedule software creators revolutionized not only the capability to perform forward-looking predictive project scheduling, but also delay analysis. One of the great inventions was the development of time impact analysis. [3]. This methodology harnessed the power of the computer and coupled it with the best of the expert's knowledge. The power of this methodology is reflected in its widespread adoption and adaptation in US federal government contracts [4].

Invariably, experts working to better identify critical paths in large complicated projects adopted and modified the TIAs to assist them in performing forensic schedule delay analysis. Unfortunately, TIA methodology in this situation is so attenuated, that its accuracy is suspect. Nonetheless, the relative ease of the methodology, heavy emphasis on technology, and seeming removal of subjective opinion, made this methodology seem more scientific and thus accurate. As such, the TIA may be more successful in Daubert challenges than the as-planned vs. as-built [5].

Perhaps the peak of this trend/fad, touting TIA as the "best methodology," occurred in the UK, in 2002, when The Society of Construction Law published its "**Delay and Disruption Protocol**," a guide book/manual on schedule delay analysis (SCL Protocol). The manual reflected the extraordinary work of many of the best minds associated with scheduling, or programming, as it is called in the UK. This impressive document discussed the relative merits of various methodologies that have been developed to perform forensic schedule delay analysis. The Protocol went further and stated the following.

> *"The Protocol recommends [the time impact analysis] methodology be used wherever the circumstances permit, both for prospective and (where the necessary information is available) retrospective delay analysis [6]."*

One of the goals of the SCL Protocol was to try to make sense of the differences between the various methodologies. There is great need for clarity on this point. A review of articles on schedule delay analysis will invariably reveal a bewildering array of choices or at least a multitude of different named methodologies [7].

These methodologies break down into the following two large groups.

- **Modeled**—those analysis methodologies that while performed after the events have occurred, try to model, in a forward-looking manner (prospectively), the events on the project; and,

- **Observational**—methodologies that observe what happened and compare that to the plan [8].

Below is a list of some of the better-known named methodologies.

Modeled	**Observational**
• time impact analysis	• as-planned vs. as-built
• impacted as-planned	• as-planned vs. update
• time impact evaluation	• windows analysis
• fragnet bnalysis	• planned vs. actual
• collapsed as-built	• contemporaneous period analysis
• but-for analysis	• update analysis
• as-built less delay	• month-to-month

The primary representatives of each of these two groups are time impact analysis (TIA) and as-planned vs. as-built (APAB) analysis. These methodologies have a number of variations and name alternatives. For the sake of clarity and comparison, here is a brief description of each of these two methodologies in their broadest context.

TWO METHODOLOGIES DEFINED

Time Impact Analysis (TIA)—This methodology models actual performance through the use of computer-generated schedules developed during the course of the project at periodic intervals, adding specific activities (fragnets) that model delays and impacts occurring during that interval. The result of the addition of these activities, in theory, changes the completion date for the project and the critical path to reach that completion date. This new impacted schedule is then updated with actual progress for the next period and the process is repeated. The goal of this methodology is to model the actual events on the project as accurately as possible and through that modeling, identify on a periodic basis the critical path, the delay or acceleration on a periodic basis, concurrency and the party responsible for delay.

As-Planned vs. As-Built (APAB)—This methodology observes what actually occurred and compares it to what was planned to occur. It measures delay by comparing actual activity dates with planned dates. It does not need a computerized schedule – it can be done with bar charts or timelines created from project records. However, it does require the analyst to make detailed analytical decisions as to which activities were critical. The methodology often uses only the original schedule for its comparisons, but can be performed on a periodic basis with updated baselines. The goal of this methodology is to describe the actual events on the project as accurately as possible and identify the critical path, the delay or acceleration on a periodic basis, and the party responsible for delay.

Clearly the objectives of the two methodologies are largely the same. It would appear from this brief synopsis that the TIA has much to recommend it – and it does. The retrospective forensic use of TIAs grew out of its original prospective purpose. This original purpose was to predict, on an ongoing basis, the effects of inserting planned changes to the work. The inclusion of TIA requirement clauses in US federal government contracts shows its widespread and deserving acceptance for that prospective purpose.

RELEVANCE OF THE PLANNED SCHEDULE

As found in the world of forensic schedule analysis, the projects which are in need of delay analysis are often those that have the weakest factual infrastructure. After all, if the facts and the law were obvious, the parties would (hopefully) have settled the dispute. It is axiomatic that most of the cases presented to forensic schedule analysts for evaluation are deficient in one or more of the proper management infrastructure elements. These projects often have incomplete or non-functional schedules; poor record keeping practices, including as-built data which is often incomplete; thin correspondence files; and contractually insufficient notices.

Unfortunately, the lack of adequate records, particularly functional schedules prepared and maintained with as-built data on a regular basis, is what holds troubled projects back from being properly analyzed after completion. To correctly perform a forensic TIA, one needs to have schedules with the following characteristics:

- The schedule should reflect the full scope of the work.
- Activities should be small in scope with relatively short durations with the exception of administrative activities.
- The schedule should reflect logical and reasonable relationships between activities and groups of activities.
- Data date for the initial schedule should be at the notice to proceed date and there should be no progress in any activity.
- There should be a continuous critical path (no gaps) from NTP (the first activity) to completion (the last activity).
- All activities (except the first and last) should have predecessors and successors.
- Internal schedule constraints should be logic driven, not fixed in time.
- The scheduled late dates should also reflect reasonable sequence and timing for construction.
- Updates should maintain appropriate logic.
- Changes should be included in schedule updates. And,
- Progress must be accurately represented in the regular or periodic updates.

The practical result of these requirements is that few projects in dispute have the necessary schedules to perform a fully defensible, "air-tight" TIA analysis. By way of example, should the only available schedules on the project be hard copy, the forensic expert has a very difficult task, for those paper schedules almost never provide the following.

- predecessor and successor lists with logic and lags;
- early and late dates, with calendar settings; or
- the total float of each activity.

Even graphic prints that purport to show logic connections are often incomplete. There is also the ever-present possibility that the original project schedule, and/or schedule updates incorporating changes, contain faulty or poor logic.

Incomplete logic in the baseline schedule or in the schedule updates defeats the accuracy of schedule analysis. The bottom line with regard to schedule analysis is that much of the work is subjective and depends upon the expertise of the individual performing the analysis. An imprecise assumption may never be recognized by those to whom the completed analysis is presented, however, the analysis remains flawed.

If this speculative procedure is repeated for several periodic updates, the question arises as to whether the schedules so generated have any reasonable relationship to what was originally intended in the schedule. If these recreated schedules are vastly different from the underlying planned schedule, the eventual trier of fact will have difficulty relating to an analysis and believing that it is factually supported. It could easily be argued that the more extensive the modifications (whether they are characterized as "corrections," "additions" or "reconstructions") the more likely the testimony based on those schedules would be subject to a *Daubert* challenge [9]. In the words of one clever government attorney, the baseline could become the "never as-planned" schedule.

In contrast, the APAB requires minimal schedule input. It can be performed with even a rudimentary bar chart developed without a CPM. Ideally, the APAB baseline schedule has many of the same characteristics described as essential for a TIA analysis. These include the following.

- The schedule should reflect the full scope of the work.
- All activities should be small with relatively short durations except for administrative activities.
- Data date for the initial schedule should be at NTP and there should be no progress in any activity.
- There should be a continuous critical path (no gaps) from NTP (the first activity) to completion (the last activity).
- Internal schedule constraints should be logic driven, not fixed in time. And,
- The scheduled late dates should also reflect reasonable sequence and timing for construction.

These items simply represent the criteria for good baseline schedules. However, APAB analyses that are based on minimal or poorly defined schedules with minimal data will provide a correspondingly crude framework for an analysis. At a minimum, the baseline schedule in an APAB analysis should contain the following.

- contractually accurate commencement and completion dates;
- compliance with all intermediate milestones; and
- a sequence of activities that are required to be performed in the sequence depicted without gaps or missing periods.

Since bar charts tend not to have a critical path in the manner now commonly understood, the identification on that bar chart of a critical sequence of work is not essential, although it will be necessary eventually to identify the as-built critical path.

If available project schedules are complete, and were periodically updated to reflect changes in logic to reflect contemporaneous planning, the schedule analyst could perform a detailed analysis on an overall or single period basis. The accuracy of an APAB analysis could be increased by performing a comparative analysis with greater frequency, on a monthly basis for example. APAB schedule analysis within discrete time periods is inherently more accurate. When performing an APAB comparison, if a single baseline (planned) schedule is used the analysis may be easier to understand. However, a single baseline schedule will not reflect an accurate representation of the latter sequence of events, since projects evolve over time. In larger projects with more activities and more changes during performance, a single update is completely inappropriate. There are, however, instances in which a single baseline may be appropriate such as if the project is of relatively short duration with relatively few activities. If accurate data is available, APAB can be done on a monthly basis. This methodology has sometimes been called a "windows" approach.

The accuracy of the APAB analysis can be assisted by the use of the Daily Delay Measure methodology (DDM). [10] In this methodology, the analyst can calculate on a daily (or any other periodic basis) basis the delay of every activity against its late planned dates. This highly mathematical approach can assist the analysis by quickly identifying candidates for the critical path. The addition of this methodology could likely assist a user of the APAB methodology to overcome a *Daubert* challenge where an allegation that the APAB is "unscientific" has been raised.

RELEVANCE OF ACTUAL DATES

Both the TIA and the APAB require actual dates. Without knowing what actually happened, the value of either analysis is greatly diminished [11]. This is well recognized by courts. In Fortec Constructors v. United States, 8 Cl. Ct. 490 (1985) discussing the importance of regular updating in order for a CPM schedule to be used in evaluating delays presented, the Court stated:

> *If the CPM is to be used to evaluate delay on the project, it must be kept current and must reflect delays as they occur. In the instant case, the CPM was updated only once, in August of 1979. This update did not consider delays in work performed prior to the update, nor, obviously, in work that occurred after the update through the date of acceptance of the project by the Corps . . . .*

In Appeal of Ealahan Elect. Co., Inc., 90-3 BCA (CCH) 23177, D.O.T. Cont. Adj. Bd. 1990, the Board discounted an expert's testimony for ignoring actual project performance. In a recent US Federal Claims Court decision, Sunshine Construction and Engineering, Inc. v. United States, U.S. Ct. Fed. Cl., 64 Fed. Cl. 346; 2005 U.S. Claims LEXIS 55, in which the Court criticized an expert's attempts to break a project into fragnets rather than comparing the planned schedule with the actual schedule updates to determine the location of the critical path through the project, the Court stated with regard to disregarding actual dates:

> *[The expert] prepared a critical path method schedule delay analysis, in which he reviewed the as-planned schedule, schedule updates, progress payments and other Project doc-*

umentation in order to construct an as-built schedule. [The expert] identified the critical path on the as-built schedule, compared it to the critical path on the as-planned schedule, and analyzed "where activities may have been performed in the same time as was originally planned, may have been performed in a shorter time that originally planned, or may have been performed in a longer time than originally planned."

In J. A. Jones Constr. Co., ENGBCA Nos. 3035, 3222, 72-1 BCA 9261, the Army Corps of Engineers Board of Contract Appeals echoed its earlier concern that the CPM must reflect actual performance to be a reliable basis for evaluating requests for time extensions . . . The board rejected the government's reliance on the original, unadjusted CPM stating:

The value and usefulness of the CPM . . . is dependent upon the contracting officer making prompt decisions when excusable delays are alleged by the contractor and upon the contractor promptly revising and updating the CPM chart to incorporate time extensions, whether they be tentative or finally determined, within a short time after occurrence of the delay.

In Continental Consolidated Corp., ENGBCA Nos. 2743, 2766, 67-2 BCA 6624 (1967) the Corps held that if the CPM schedule is used to evaluate requests for time extensions, the schedule must reflect actual conditions, stating:

It is essential that any changes in the work and time extensions due to the contractor be incorporated into the progress analysis concurrently with the performance of the changes or immediately after the delay and thus integrated into the periodic computer runs to reflect the effect on the critical path. Otherwise, the critical path chart produced by the computer will not reflect the current status of the work performed or the actual progress being attained.

For the TIA, as-built data used is usually that which has been incorporated into the schedule as part of the updating process. Therefore, if project schedules were maintained and usable, the analysis has an automatic data source which merely requires checking for accuracy. The TIA requires only the proper start and completion dates of activities. Intermediate work and progress dates are virtually never identified, and are not able to be considered in the analysis. However, since the TIA analysis requires recreating the schedules to represent periodic planned schedules, the as-built data will have to be added, the source of which may be those same incomplete project records. Because of the importance of as-built dates, forensic schedule analysis should include the confirmation of those dates. At one extreme, the analyst can assume the dates in the update are correct. Generally, however, this is a foolish assumption. A better practice is to confirm the accuracy of a sample of dates or each start and finish date [12].

The APAB takes no such ready-made source for as-built data. The development of a detailed as-built database can be very expensive and may not be worth the effort. However, complete and accurate as-built data is essential for an accurate analysis. The analyst is faced with the following two alternatives.

- an as-built showing only start and finish dates; or
- a daily specific as-built (DSAB) that identifies on a daily basis the activities in progress [13].

While many forensic delay analyses can be completed and be considered accurate based solely on the start and finish date of activities, many projects need to identify the day-by-day progress since the critical path could shift between activities during performance of that activity. In that regard, the development of as-built data should follow the following steps.

Creating an Independent As-Built Schedule from Scratch

- An as-built record of the work on a project is often necessary to verify the accuracy of the CPM dates reflected in the various schedule updates and to identify and correlate events that may have occurred inside a single CPM activity. This identification of events inside a CPM activity is essential to demonstrate possible shifts in the schedule and explain responsibility for any delays to a particular activity.
- The best source for as-built data is a continuous daily history of events on the project developed and maintained by persons working on the project. Traditionally, there are contractor's daily reports but there may also be owner's daily inspection reports or a scheduler's daily progress reports. These daily records can be augmented as required by other primary sources such as completion certificates, inspection reports, incident reports and start-up reports. Secondary sources such as weekly meeting minutes, or progress reports can also provide insight into what happened.
- It is often best to develop the DSAB schedule using a database where every entry from the daily report is separately listed as a record. Such a database would allow complete history of each activity over time, or an electronic version of the daily report coded for activities worked on a particular day. Notes on the daily reports such as problems or delays can be listed as additional activities.
- It is important to develop a correspondence between as-planned activities and as-built activities. Baseline schedule activities usually include descriptions sufficient to distinguish them from other similar activities. The as-built schedule is coded to the same activities included in the baseline schedule. It is frequently the case that there is not a perfect match between the activities in the two schedules. Some as-planned activities may not appear in the as-built, and, more frequently, there are significant as-built activities that are either in greater detail than in the as-planned, or simply do not appear in the as-planned schedule.
- Identifying the true "start" of an activity is essential. It is usually relatively easy to identify from the as-built data the start of an activity, but not always. It is recommended that the start of an activity be considered the first date associated with a series of substantive work days on the activity.
- Identifying the true "finish" of an activity is also important. The same logic as above applies to finish dates. However, in most cases it is appropriate to use the "95 percent rule."

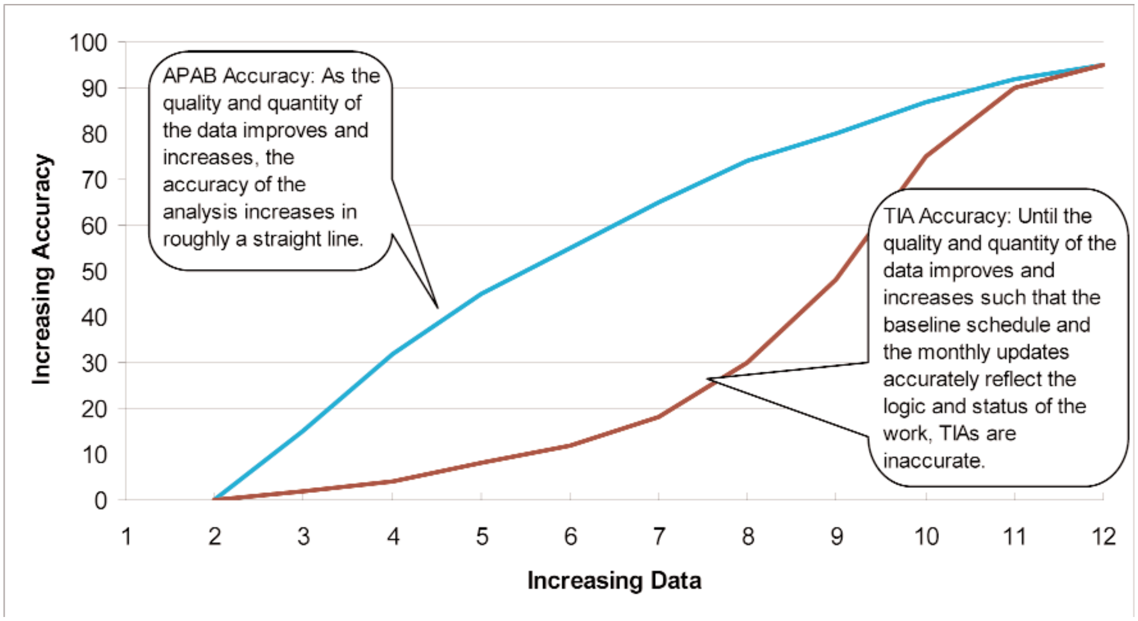

Figure 1—Accuracy vs. Data

> This rule recognizes that many activities are functionally "complete" prior to the work being fully finished (95 percent complete), as their successor activities may no longer be hindered from progressing. Generally the analyst, absent specific data to the contrary, should assume that when the period of concentrated work is completed on an activity, the activity is complete.

The as-built schedule has a second and perhaps more fundamental function. If a DSAB is developed (admittedly at significant cost), the analyst can identify specific events on a daily basis and identify non-work periods, small scale impacts or overly simple activity structure.

For example, if the contractor depicts exterior light-gauge framing as an activity followed by sheathing, it may be essential to perform a daily analysis, since such framing will include both wall framing (possibly on the critical path) and parapet framing (unlikely to be on the critical path). Only a detailed look at the events on a daily basis is likely to reveal this level of detail.

As discussed in the preceding paragraphs, the accuracy of the baseline schedule and as-built dates are crucial for accurate forensic analysis. The greater the accuracy and completeness of the data, the more accurate the forensic analysis. This is illustrated in figure 1. Both the TIA and APAB become more accurate as the quantity and quality of the data increases. However, because of the need to fill in and interpolate missing data for TIAs unless there are properly developed and maintained schedules, the likely accuracy of a TIA based on minimal data will be significantly lower than that of the corresponding APAB. Thus, a visual representation of this concept would have the TIA curving up steeply in accuracy only after a significant portion of correct data is acquired.

In addition, a TIA requires as-built data recording the start and completion of activities. If proper schedule maintenance has been performed, these dates may be maintained in the schedule update files. However, in schedules that are being recreated to represent the periodic planned schedules, as-built data will also have to be added, most probably based on those same incomplete project records.

ROLE OF FRAGNETS

As discussed above, TIA analysis has the following two parts.

- the schedules; and
- the fragnets.

Fragnets play no role in an APAB analysis, because actual durations and activities are used to represent what actually happened. However, they are essential to TIAs, as prospective activities are inserted to see the potential impact of schedule changes or additional activities. A fragnet is a portion or fragment of a CPM logic diagram. As such it has the following characteristics.

- it contains one or more activities or events with a positive duration;
- those activities are logically connected to each other; and
- the fragnet as a whole is logically connected into the project schedule by creating a logic tie to a predecessor activity and a successor activity.

It is apparent that development of fragnets is a very important step in the TIA process. In order to ensure TIA accuracy, forensic analysts often develop fragnets for every change order proposal on the project. Such a policy assures that someone has identified and quantified the necessary logical connections such additional work will have on the remainder of the project. Most of these fragnets will have no impact on the completion of the project – in other words they will not delay completion due to the fact that most change orders do not impact the critical path. Since many contractors have a policy to develop change order proposals for every conceivable event not clearly within the contract scope, there can be, and often are, hundreds of fragnets. Further, these fragnets can, in and of themselves, be relatively complicated since they will mimic the changes in scope.

But while the development of fragnets may seem to be a straightforward task, in forensic analysis, it takes on a special life. The analysis, whether consciously or unconsciously, can develop fragnets that have varying impact on the critical path. In other words, the analyst can manipulate the fragnet to show a desired effect. The following are three ways that an analyst can manipulate the effect of fragnets inserted into a TIA.

- inclusion/exclusion;
- logic connections; and
- durations.

The first and most fundamental decision an analyst can make is the decision to include or exclude a fragnet. For example, an expert working on behalf of an owner performing a forensic TIA analysis could choose to not to include one or more fragnets under a theory that his expertise concluded it could not possibly have had an impact. Alternatively, the expert working on behalf of a contractor could include every event conceivable fragnet to mimic the events or could divide a single event into multiple fragnets, possibly magnifying its effect. In either case, the expert controls the outcome through his decision process. Further, since these sorts of decisions are often hidden within appendices to expert reports, the full subjective scope of an expert's decision process is often hidden – masked beneath seemingly objective facts.

The second possible manipulative device is the number and type of logic connections the analyst employs. Since the fragnet itself is an assemblage of a few logic ties and a few durations, these decisions are obviously the most fundamental. But again, the full impact of these decisions is often masked by the sheer number of them and their "scientific" impenetrability to most non-schedulers. For example, if an owner were to decide to install a different air handling unit after the original one had been installed, how would the forensic analyst develop the fragnet? There are at least two different approaches.

- what actually happened; or
- what should have happened.

In our example the fragnet will contain the following activities, as shown in table 1.

Act. No.	Activity Description	Duration
H1030	Original equipment is connected to piping	NA
F100	Owner Identifies new HVAC Equpment	1
F101	Owner Authorizes work to proceed	1
F102	Contractor orders equipment	1
F103	Equipment is manufactured and delivered to the site	60
F104	The old equipment is uncoupled from piping	2
F105	The old equipment is removed	2
F106	New equipment is installed	3
F107	New equipment is Connected to piping	2
H1040	Test HVAC	NA

Table 1—Fragnet Activities

This seems relatively straightforward but does the contractor uncouple and remove the HVAC unit while the new one is being manufactured? Or does the contractor wait until the new unit is delivered to make sure it will arrive correctly and minimize the equipment lifting procedure by removing the old and

Activity ID	Activity Description	Orig Dur	%	Early Start	Early Finish	Total Float
H1030	Original Equipment is Connected to Piping	5	0	02JAN07	08JAN07	9
H1040	Test HVAC	10	0	09JAN07	22JAN07	9

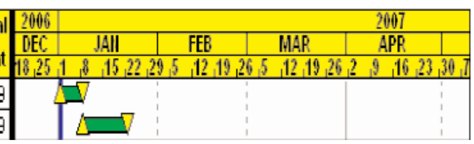

Figure 2—Example of As-Planned

Activity ID	Activity Description	Orig Dur	%	Early Start	Early Finish	Total Float
H1030	Original Equipment is Connected to Piping	5	0	02JAN07	08JAN07	-63
F100	Owner Identifies New HVAC Equipment	1	0	09JAN07	09JAN07	-63
F101	Owner Authorizes Work to Proceed	1	0	10JAN07	10JAN07	-63
F102	Contractor Orders Equipment	1	0	11JAN07	11JAN07	-63
F103	Equipment is Manufactured and Delivered to Site	60	0	12JAN07	05APR07	-63
F104	Old Equipment is Uncoupled from Piping	2	0	06APR07	09APR07	-63
F105	Old Equipment is Removed	2	0	10APR07	11APR07	-63
F106	New Equipment is Installed	3	0	12APR07	16APR07	-63
F107	New Equipment is Connected to Piping	2	0	17APR07	18APR07	-63
H1040	Test HVAC	10	0	19APR07	02MAY07	-63

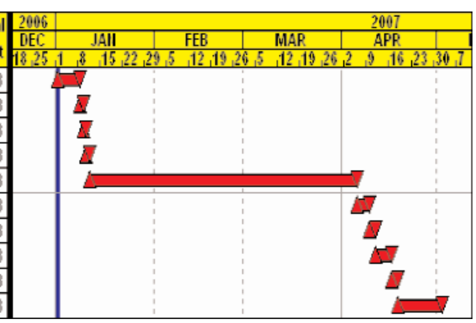

Figure 3—Example of As-Planned with Fragnet Option A

Activity ID	Activity Description	Orig Dur	%	Early Start	Early Finish	Total Float
H1030	Original Equipment is Connected to Piping	5	0	02JAN07	08JAN07	-59
F100	Owner Identifies New HVAC Equipment	1	0	09JAN07	09JAN07	-59
F101	Owner Authorizes Work to Proceed	1	0	10JAN07	10JAN07	-59
F102	Contractor Orders Equipment	1	0	11JAN07	11JAN07	-59
F103	Equipment is Manufactured and Delivered to Site	60	0	12JAN07	05APR07	-59
F104	Old Equipment is Uncoupled from Piping	2	0	12JAN07	15JAN07	12
F105	Old Equipment is Removed	2	0	16JAN07	17JAN07	12
F106	New Equipment is Installed	3	0	06APR07	10APR07	-59
F107	New Equipment is Connected to Piping	2	0	11APR07	12APR07	-59
H1040	Test HVAC	10	0	13APR07	26APR07	-59

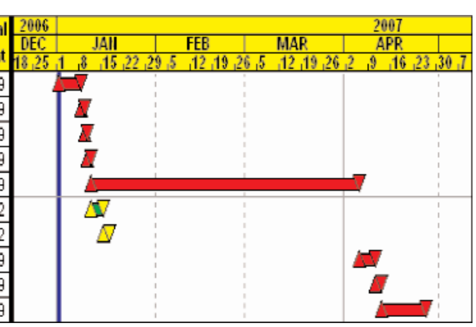

Figure 4—Example of As-Planned with Fragnet Option B

inserting the new as a single operation, thus saving money? These differing assumptions could change the impact of this fragnet by four calendar days. Figure 2 illustrates this difference.

Figure 2 shows only the initial two activities before the incorporation of the fragnet. The total float of these activities shows as nine workdays. Next, the fragnet activities F100 through F107 are added to the schedule. The contractor waits until the new equipment is delivered to the site before removing the old equipment at which time the new equipment is installed.

Because of the added activities impacting the test HVAC activity, the total float has changed from nine workdays to -63 workdays. If the contractor chooses to remove the old equipment before the new equipment is delivered, the impact will be lessened.

Because of the removal of the old equipment from the critical path, the total float has been improved by four workdays to -59 work days. The analyst, therefore, can influence the overall effect of a fragnet by his assumptions concerning the logic and sequence of the work.

The third method of possible manipulation is found in the durations the forensic analyst uses in the fragnet. In prospective TIAs this is not an issue since the work has yet to be performed and, therefore, the only possible duration to insert is a forward-looking estimate. However, in the case of a retrospective forensic TIA, the analyst can choose either the duration that would have been inserted into the TIA had the work yet to be performed, or the actual duration can be inserted.

The advantage of inserting the actual duration is that it will most closely mimic actual project events and generate a critical path that is more likely to reflect reality. The advantage of inserting the duration that would have been estimated contemporaneously is that it more closely reflects what was happening on the project at the time and provides a more realistic snapshot of what management would have seen looking forward. Unfortunately, many analysts will decide which to use based on who is their client. If the client is a contractor, the analyst will probably present his client in a better light if he chooses projected durations. If the contractor was accelerating, and actual durations were shorter than projections, then using the projected durations would magnify the amount of acceleration accomplished. If the contractor was not accelerating, projected durations would tend to minimize the anticipated delay. Conversely, if the analyst was working for the owner, it would likely be in the client's interest to always choose the actual duration as this would minimize any acceleration and maximize any increased delay by the contractor.

IDENTIFICATION OF THE CRITICAL PATH

The APAB analysis technique, which compares planned dates to actual dates in a cumulative and sequential manner from the outset of the project to completion, generates a critical path. As discussed previously, expert opinion is essential to correctly identify the critical path and avoid incorrect logic that may have been present in the baseline schedule and reflect changed logic that occurs during the course of performance. For example, the flagpole installation is not likely to ever be on the critical path.

Since the analyst is making the determination, the APAB methodology has been criticized as being too dependent on opinion and not readily reproducible in order to qualify as scientific fact. But if that opinion is "expert opinion" based on a thorough review of the schedule and the facts, it probably is more accurate that rote reliance on the logic identified in the schedule. Further, by the additional use of the DDM methodology, the vagaries of expert opinion are reduced and the transparency of the choices made is enhanced. The expert analyst is identifying the timing of actual events that were controlling the forward progress of the work, whether they were perceived as such at the time or not. It often happens that such an analysis does differ from contemporaneous updates and memories of the participants. Certainly in such situations, the expert must evaluate all the data to assure that his conclusions are correct.

However, schedule updates are not always accurate; they may have been adjusted by the contractor to hide or enhance certain activities, or they may simply be improperly updated by inadvertence. It is recognized that as work on the project advances, the projected logic changes to reflect past occurrences and if that logic changes too radically, then a new baseline schedule or a "re-baseline" must be used in the APAB analysis. The result in any APAB analysis will be the identification of the as-built critical path. That critical path will follow the original logic of the project and then be adjusted through the expert's recognition of actual modifications that occurred to that logic and normal variations from the planned performance. In all situations however, the critical path will be based on what happened, not what was anticipated to happen.

The critical path in a TIA is always a projection of what may occur. The TIA critical path is a series of forward-looking critical paths. For example, if the TIA is done on a monthly basis, the critical path for the first month of the project is the projected critical path as of NTP. The critical path for the second month is the projected critical path calculated at the end of the first month looking forward. In this manner, the TIA critical path is never actually what happened, but is always a projection of what is anticipated to happen. Assuming the TIA was done in the best manner possible, this forward looking critical path will usually be close to the actual critical path unless significant changes occurred during the course of a month. If significant changes to work on the project did occur, then the proper TIA methodology would be to perform a new TIA snapshot at the time of the change so the alterations in the critical path more closely reflect the timing of the events.

This raises another potential problem with TIAs. If the periods used for the TIA are too long, even if regularly occurring, they may be missing key changes that could affect the critical path. Careful selection of the periods when each TIA projection is performed is a key element in the analyst's application of a TIA methodology. By selecting a period that excludes certain events, an analyst may be excluding certain fragnets that ought to have been inserted. The selective exclusion of fragnets is mentioned above in more detail.

Identification of Responsibility Along the Critical Path

Both the TIA and the APAB require expert evaluation of facts if a determination as to culpability for delays along the critical path is to be made. In both methodologies, the analyst reviews the events along the critical path, identifies delay events, and reviews reasons for the delay. While the mechanics of quantifying delay may vary slightly between these two methodologies, the process of determining responsibility is largely identical.

The Role of Concurrency

Most analysts believe that the TIA is better at representing concurrency. Regardless of one's definition of concurrency, it is true that a properly performed TIA will most clearly and "scientifically" identify concurrent activities within each time period analyzed [14, 15]. This is because each of the inserted fragnets will show what, at a given point in time, was critical during each period analyzed. With the TIA, future events that affect a yet-to-be accomplished activity are not relevant to the current period's (or window's) events. Thus, the criticality of an impact can be shown at the point in time it becomes effective and concurrencies are better sorted through in this way. In other words, any overlap in duration of the potential concurrency can be more accurately measured than just reviewing an updated schedule which may or may not contain the delay events.

Since concurrency is a major concern to most triers of fact, such identification of multiple concurrent critical paths is useful. However, it is a misconception to believe that an APAB does not provide identification of concurrent critical paths. By rebuilding the precise time and delay events that occurred and verifying (or rebuilding) the actual dates of the schedule, the critical path or paths and the delay impacts on each critical path is identified by its lack of float. This identification allows the analyst to determine which delay impacts are concurrent, which are staggered, and which are near critical versus precisely critical with less subjectivity than if only projected dates were used. Within these critical and near critical, concurrent and nearly concurrent paths, an expert may have to make some final determinations as to his/her opinion on what was driving the critical path of the project when and by exactly how much. The final determinations and opinions by an expert in his/her report regarding which paths are critical is where much of the criticism arises; however, the same subjectivity is applied when using a TIA. The TIA similarly requires determinations that affect the critical path such as which time periods (or windows) to study, how much planned duration to give the fragnet, which impact events to include, etc., [16].

TIAs are important and incredibly useful tools for schedule analysis. Contractors would be hard-pressed to identify, and quantify, potential schedule impacts without prospective use of the TIA methodology, the methodology for which the TIA was developed. It has also been said that a forensic TIA is better able to identify the "quantum" of the acceleration by comparing the actual performance with what would have happened without acceleration [17]. However, in the world of forensic retrospective analysis, TIAs have the following problems:

- TIAs appear to be scientific and computer driven; however, they are subject to similar vagaries of expert opinion as APAB.
- TIAs hide or obscure the ability to manipulate the critical path through the development and use of fragnets and its inclusion, logic connections, and durations.
- TIAs require a detailed and fully functional baseline schedule and set of updates to work properly—a requirement that is often impossible.
- Modifications to the baseline schedule and updates that are needed to permit TIA analysis can be so significant as to make the underlying schedules irrelevant to the plans of the contractor. And,
- The critical path generated is always a projection and may not accurately reflect the actual events on the project.

The corollaries to these disadvantages are the advantages of APAB, including the following.

- APAB are clearly expert driven, so the trier of fact must consciously evaluate the expert function.
- The very expert function requires transparency underlying that opinion; they cannot obscure or hide their decisions.
- The APAB can be performed with less than ideal schedule data, a fully functional baseline is not necessary.
- The expert analyst can simply use the baseline schedule as it is found, questionable modifications are not required.
- Most importantly, the APAB focuses more directly on the as-built critical path so the trier of fact can evaluate all the facts and opinions that lead to that path. The focus can remain on what actually happened, as opposed to the modeled events predicting what might happen.

In addition, the APAB is simple to understand and relatively simple to perform. It can be used even when the underlying schedule material or actual data is less than perfect. The APAB analysis methodology is more transparent. It is more evident where expert opinion is being exercised and conclusions are being made.

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