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Forensic Schedule Analysis Methods: Reconciliation of Different Results

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Abstract

Perceived wisdom within the construction industry is that different Forensic Schedule Analysis (FSA) methods produce different results on the same set of facts. Although there are many potential variables that could cause this, such as bias of the analyst or the quality of the implementation of a method, some experts have expressed concern that the methods themselves generate different results and are therefore some may be potentially defective. But do the different methods actually generate different answers when applied properly to the same set of facts, or are the observed differences natural aspects of the methods that can be documented and quantified? This paper will explore that question by examining a specific set of facts and applying each of the four major FSA methods – the As-Planned vs. As-Built, Contemporaneous Period Analysis, Retrospective TIA, and Collapsed As-Built – to those facts. Further, if the methods do generate different results, the paper will explain how and why that occurs, how to quantify and reconcile the differences, and what conclusions a FSA expert should draw from those differences.

Forensic Schedule Analysis Methods

Forensic Schedule Analysis (FSA) is the applied use of scientific and mathematical principles, within a context of practical knowledge about engineering, contracting, and construction means and methods, in the study and investigation of events that occurred during the design and construction of various structures, using Critical Path Method (CPM) or other recognized schedule calculation methods. [5] An analyst begins an FSA with a review and analysis of the planned construction sequencing in the baseline model, calculation and analysis of activity duration (with respect to planned quantities, estimated resources, and productivity levels), activity sequencing, resource scheduling, and evaluation of the trade-offs between cost and time. The analyst then, either by using the existing model (CPM schedule) or by creating mathematical or statistical model, in order to analyze, in a verifiable and repeatable manner, how actual events interacted with the baseline model and its updates in order to determine the significance of a specific deviation or series of deviations from the baseline model and their role in determining the ultimate sequence and duration of tasks within the complex network. [4] The form that the mathematical or statistical model takes defines the analysis "method."

AACE's "Recommended Practice on Forensic Schedule Analysis" (RP 29R-03) is a unifying technical reference developed with the cooperation of dozens of experienced FSA experts, and the analyses performed for this paper were conducted in keeping with the principles and method implementation protocols (MIPs) described therein. There are nine MIPs overall; however, the RP breaks the methods into four major families: the As-Planned versus As-Built (APAB/MIP 3.2), the Contemporaneous Period Analysis (CPA/MIP 3.5, sometimes commonly called the "Windows" method), the Retrospective Time Impact Analysis (RTIA/MIP 3.7), and the Collapsed As-Built (CAB/MIP 3.9). The further breakdown of the families into the nine methods – the MIPs – is defined by factors such as timing of the analysis, whether the model relies on active CPM calculations or not, whether the model adds or subtracts fragmentary networks ("fragnets") to simulate the effects of delays, or whether the analysis is performed globally or in periodic steps. [6]

A definition of the term "window" is necessary to avoid confusion between the many uses of the term. Although the term "Windows" is sometimes used as a term to describe a specific analysis method, it is important to understand that a window is a slice of time in the life of a project, within which the analyst will use the selected method to examine that window's events. Most of the methods can be implemented in a way that subdivides the project duration into windows. The choice and definition of the periods of time used to form the windows will be dependent on the circumstances. However it is common practice to time the start and finish of the windows to coincide with the monthly progress update and pay application. Occasionally the start and finish points for windows are identified to correspond with specific delay events which are of interest to the analyst. Although this is potentially valuable, it is inadvisable to have analysis windows which are wider than the period encompassed by the progress updates. The monthly update (or pay application date, if no updates exist) should be the maximum width of a window. [21]

One of the more important differences between the forensic methods relates to how it treats the project management team's understanding of the critical path work, and whether the contractor and the owner used the schedules during the project to establish their beliefs regarding which work was driving project completion and then used that knowledge to plan the upcoming period's work. What the project management team knew is called its "contemporaneous understanding of criticality." From the perspective of the project management team that is properly using their prospective schedules for planning and executing the next period of work, their knowledge of what was critical to project completion (and therefore the explanation of their actions at the time) is related to the status of the critical path at the time in question. Even in the case where future events shift the final as-built critical path away from an activity that was considered critical at the time, the understanding of the project management team's actions is possible only by understanding what they thought was critical at the time. A major difference in the analysis methods involves whether (and how) they incorporate the contemporaneous understanding of criticality. Some methods rely heavily on the contemporaneous view of criticality, while others determine criticality in a different way (such as the determination or calculation of an "as-built critical path" which may or may not have a relationship to the contemporaneous critical path). The authors and many commentators believe FSA methodologies that reflect the contemporaneous understanding of criticality is preferred. [1], [20] Graphic 1 provides a general overview of the role of the contemporaneous view of criticality in FSA methods; however, the specifics of that role will be discussed in more detail later.

Common Name	MIP	Reliant upon Contemporaneous View of Criticality	Notes
As-Planned vs. As-Built (Single Step)	3.1	No *	RP 29R-03 allows for inclusion of the contemporaneous view in the definition of the ABCP.
As-Planned vs. As-Built (Multiple Step)	3.2	No *	RP 29R-03 allows for inclusion of the contemporaneous view in the definition of the ABCP.
Contemporaneous Period Analysis	3.3	Yes	
Bifurcated Contemporaneous Period Analysis	3.4	Yes	
Recreated Contemporaneous Period Analysis	3.5	No	
Impacted As-Planned	3.6	No	
Retrospective TIA	3.7	Yes *	The inserted fragnets must also have been contemporaneously understood to affect the CP.
Collapsed As-Built (Single Step)	3.8	No	
Collapsed As-Built (Multiple Step)	3.9	No	

Graphic 1: The Role of the Contemporaneous View of Criticality in FSA Methods

However, a contemporaneous understanding of criticality can only exist on projects that have a valid contemporaneous schedule series. The fact is that some projects have schedule series that do not represent the contemporaneous planning. Sometimes such schedule series stem from an adversarial relationship between the parties that develops during performance of the work. These schedules are generally unsuitable for use in a forensic analysis. [19], [23] Other projects do not have schedules at all – even, sometimes, despite the fact that the contract mandated their use. [14] As will be discussed, the perspective on the contemporaneous understanding of criticality selected by the analyst will have a significant impact on the results of the analysis.

Do we need a paragraph about why we think a contemporaneous view of criticality is important?

The fact of whether or not a contemporaneous understanding of criticality was reflected in a schedule should be a factor in determining which method is best for analyzing a given project's delays. For instance, if a project had update schedules created by a scheduler off-site that were never reviewed by the project management team, it is probably not appropriate for a forensic analyst to choose a method like the CPA/MIP 3.3 to analyze that project. Conversely, an analyst would likely be in error in selecting the APAB/MIP 3.2, which does not inherently consider the contemporaneous understanding of criticality, to analyze a project that had a good series of schedules used by the project manager and superintendent to plan and execute the project. In addition to the other factors to consider in selecting an appropriate FSA method, therefore, the analyst should also consider how the schedules were used and whether they influenced the decision-making process during execution.

The Differences in Results

A common criticism of the four major methods of examining is that different methods applied to the same set of facts yield different results. Several practitioners have previously examined these criticisms. [24] Although there have been varied results from the studies, it is generally accepted wisdom in the industry that the four major methods return different results when applied to the same set of facts. This has created a perception in some that some or all of the methods are invalid. Further exacerbating the problem is the fact that professional practitioners of FSA seem apparently incapable of explaining the differences and reconciling them, which can result in the analysts engaging in a "battle of the scheduling experts" that does little to efficiently resolve disputes.

First, many of the problems with reconciling the results of competing analyses stem from other, non-mathematical sources. These problems include but are not limited to the incorrect selection of a method, the poor implementation of a MIP, or the use of a schedule series that is unreliable, unverifiable, or otherwise not capable of supporting a forensic analysis. These factors continue to cause problems with dispute resolution where competing delay analyses are involved; however, the methods proposed in this paper are not expressly designed to correct for these factors. Instead, the authors anticipate these methods being chiefly used when two competently prepared analyses are in conflict as to the existence, quantum, and responsibility of delays. That being the case, we do also anticipate that aspects of these methods could be employed to identify a poor analysis and to highlight its deficiencies.

An aspect of the FSA methods that is often disregarded in this discussion, however, is that the methods tend to analyze the schedule model in different ways. The APAB, for instance, measures "what actually happened" by using hindsight to calculate the As-Built Critical Path (ABCP) and measuring delays along this path. In contrast to this, the CPA measures what the project team believed to be critical as of a given schedule's data date, and the impact that events had on the contemporaneous CP. The shifting nature of the CP is well documented and understood, and the ABCP and the contemporaneous CP may not be the same. The CP shifts over time – sometimes between updates – until it ultimately comes to rest on the final day of the project. Therefore, an analyst performing an APAB may determine that, for a given window, the project lost, for instance, 23 CD due to activities on the APCP, whereas the opposing analyst performing a CPA would determine that during the same window, the project lost 30 CD due to an activity on the contemporaneous CP that does not ultimately appear on the ABCP. This fundamental disagreement between methods is common but not insurmountable.

In order to overcome the problems caused by the differences in the methods, we recommend a common communication format: the cumulative delay graph. "Cumulative delay" is the number of days of delay that have accrued through a given point in time. In order to generate a cumulative delay graph, one must plot the number of days of delay that an analysis shows the project to have suffered as a function of each date during the project. The source and the frequency of the data points for the cumulative delay graphs will vary slightly between methods. Most notably, the cumulative delay graph for the APAB should be plotted as the Daily Delay Measure (DDM) graph. [16] For the CPA, RTIA, and CAB, the days of predicted delay should be plotted as of the data date of the schedule at which the delay days are shown to have accrued. As will be discussed further, the resulting graph can assist in identifying reasons for differences in specific windows of the project, thereby facilitating resolution.

We see the cumulative delay graph as part of a larger reconciliation process between methodologies. For our comparison of the number and timing of delay days generated for each methodology, we have undertaken the following seven steps:

1. The source data is validated as a prerequisite to method selection.
2. As part of the method selection process, [7] the project records are examined to determine whether the contemporaneous view of criticality should be a primary determining factor in deciding which method to use. As with all parts of the method selection process, this decision should be supported with evidence.
3. The causal activity for a window must be identified. The causal activity should be determined on as frequent a periodicity as the analysis method will allow.
4. The DDM line should be plotted. This line will serve as a baseline for comparison of all the other analyses. The DDM will serve as the cumulative delay graph for the APAB analysis.
5. Each of the analyses is then plotted on a cumulative delay graphs. Each data point should be the predicted completion date of the schedule as a function of that schedule's data date. We overlaid all the lines onto a single graph for easy comparison.

6. Each window of the project duration is reviewed, and the causal activities identified by each analysis, and the amount of delay determined to have accumulated as a result of that causal activity are noted. Similarities in the causal activity and the quantum of delay allow for agreement between the parties and resolution of delay related to that specific window.
7. Differences in either causal identification or in quantum were identified and explained. The differences should be able to be explained as resulting from the differences in the perspectives of the analysis methods.

The purpose of this procedure is to first and foremost underline the fact that there are documentable and quantifiable reasons why two competent analysts of the same project could return different results. This will not, of course, resolve differences in opinion about the underlying reason why a causal activity was delayed. If both parties identify the same activity and similar quanta, but have different opinions about why that specific activity was delayed and therefore apportion responsibility differently, this reconciliation process will not help resolve that issue. However, if that is the case, then the dispute is no longer about the schedule analyses and is instead properly concerned with the facts of the case.

Creation of the Test Schedule Series

The ability to reconcile the results of different methods hinges in part on an understanding of the normal differences that will be exhibited by the cumulative delay graphs of each method. In order to establish and analyze these differences, the authors created a test schedule series consisting of a baseline schedule, 37 updates, an as-built schedule, and a collapsible as-built schedule. We did this, rather than use an existing schedule series from a past project, to avoid as many of the problems associated with poor scheduling practices as possible. Additionally, it allowed us to control the update schedules and eliminate logic revisions between the updates.

The baseline schedule was based on a hypothetical bridge construction project, wherein an existing bridge with two separate spans was being replaced, one span at a time, with active traffic shifted to the other span. The proposed maintenance of traffic plan mandated that a single span be open to two-way traffic during the construction; therefore, the general process for construction involved switching all traffic to the existing span, demolishing the abandoned span, construction of the new span, and switching all traffic to the new span. The second existing span would then be demolished and the second new span constructed in its place. The original baseline schedule contained over 432 activities, and had a Notice to Proceed date of 1-Mar- 2010, and a predicted completion date of 7-Jun-2012.

In order to create the test series of schedules for use in this analysis, the authors took a copy of the baseline schedule and created new durations which would represent the ultimate actual durations of the activities. These durations were created based on a series of theoretical productivity problems that a bridge project encountered. The new durations were input into the copy of the baseline schedule, and this schedule was recalculated as of the original Data Date of 01-Mar-2010. The authors then created a total of 17 activities that represented delays that occurred during this project. Five of these activities represented contractor-caused delays (such as start delays or rework issues) while the remaining 12 activities represented owner delays. These 17 activities were tied into the network of this schedule, with appropriate predecessors and successors for the issue described by the delay activity. The schedule was recalculated, again as of the original data date of 1-Mar-2010. The new predicted completion date of the schedule was 19-Apr-2013, or 316 calendar days (CD) after the baseline predicted completion date. This schedule contained no dates assigned to the actual start or finish columns, and as a result the network calculations were driving all the dates and float calculations; however, it did represent the actual progress of the project. This schedule therefore was capable of serving as the “Collapsible As-Built” schedule. [9]

The Collapsible As-Built schedule was used to calculate the As-Built Critical Path (ABCP) of the project, and was also used in the performance of the Collapsed As-Built analysis. To create the fully actualized As-Built schedule, the authors applied progress across the entire project, thereby making the start and finish dates in the Collapsible As-Built schedule into actual start and finish dates. This As-Built schedule had a data date of 1-May-2013.

To create the test series of 37 update schedules necessary for portions of this analysis, the authors extracted the actual start and finish dates, and the actual durations, from the As-Built schedule, and input them into a de-progression spreadsheet. This spreadsheet was designed to allow the user to estimate a remaining duration of an activity at a given point in time. Therefore, we were able to enter the desired data date of the first update schedule (in this case, 1-Apr-2010) and the spreadsheet would return a list of activities that would have started and finished, as well as a list of activities that only would have started. For these activities, the spreadsheet also gave a remaining duration, based on an assumption of straight-line progress between actual start and actual finish. The authors then copied the Baseline schedule and imported the “actual starts, actual finishes,” and remaining durations for the activities that would have seen progress during the update window. The schedule was then recalculated as of the new data date, and the predicted completion date was recorded. This process was repeated for each of the 37 months for which the project was in progress.

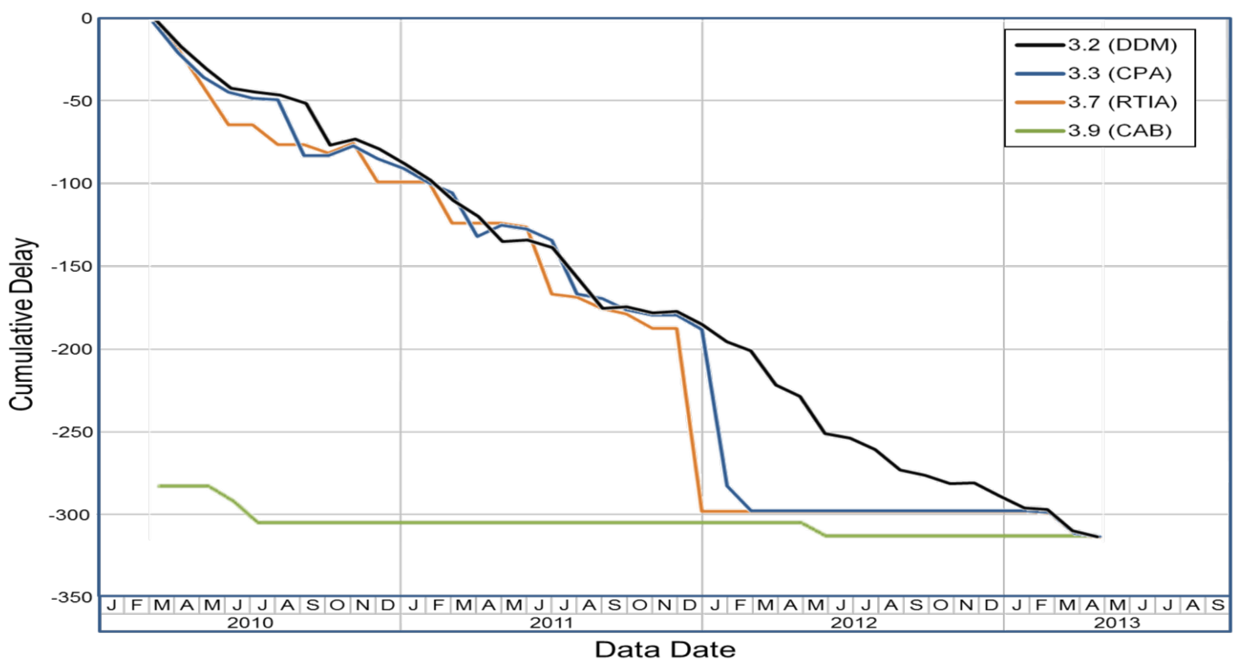
The schedule series was also created with a “weather exclusion period” that was simply a non-work period in the calendar assigned to asphalt work. According to the calendar, no asphalt work could occur between the start of the third week in December and the end of the second week in March. Any asphalt activities that were pushed into this non-work period would immediately jump forward three months, when the weather would presumably be warm enough to place asphalt. This is a common technique in construction schedules to represent periods during which no work can be performed on a type of work for a specified period, and it has a magnifying effect on delays.

For instance, assume that in the test schedule update for June, an asphalt activity is shown as completing in early December. Lack of progress in the window (June to July) creates a three week delay that pushes that asphalt activity into the weather exclusion period. Because the calendar with the weather exclusion period will not allow the asphalt work to start until mid-March, the three week delay that occurred in June has now become a three month delay. This is also a common source of dispute in apportionment of delays in a forensic analysis, since in many cases there are multiple parties responsible for the delays leading up to the point where the weather exclusion period is affecting the predicted completion date . As that is the case, disputes often arise over who is assigned the magnified delay that occurs when the schedule's predicted completion date jumps across the wide non-work period.

The 39 test series schedules that were originally created represented the contemporaneous updates that the analyst would receive as the project record schedules. These schedules were then copied (as necessary) and used to implement the four analyses. Clearly, the four methods require different schedules for performance: the APAB requires only the baseline schedule and the as-built; the CAB requires the collapsible as-built schedule; the CPA requires all the schedules as they existed during the project; and the RTIA requires all the schedules as well as the fragnets for insertion into the schedules.

Creation of the Cumulative Delay Graphic

The combined cumulative delay graph is shown in Graphic 1. The black line represents the DDM line, generated from the comparison of the as-planned dates in the baseline to the actual dates in the as-built. The cumulative delay graph for each method was developed by calculating the predicted completion date for each schedule in the analysis method's series of schedules, and plotting that predicted completion date as of the data date of the schedule within which it was calculated.



GRAPHIC 1: Combined Cumulative Delay Graphs

Generally, it is clear that the cumulative delay graph for the CAB (MIP 3.9) (in green) diverges the most from the other three analyses. The APAB (MIP 3.2) DDM line (in black), the CPA (MIP 3.3) line (in blue), and the RTIA (MIP 3.7) line (in orange) run along a largely similar path between March 2010 and December 2011; after this point, the CPA/MIP 3.3 line and the RTIA/MIP 3.7 line both drop precipitously, whereas the APAB/MIP 3.2 DDM line continues along roughly the same slope as before this point. Analysts seeking to reconcile the differences between methods must understand the causes and implications of these differences, and how it relates to the specific way the method analyzes the CPM schedule and measures delay.

Note that the authors have calculated the slope of the cumulative delay lines in units of calendar days per month (CD/Mo). Since a project cannot experience more delay in a month than the duration of that month (in absence of an inserted fragnet) the maximum natural slope of an unedited network will not exceed roughly 30 CD/Mo. Any time periods with slopes greater than the maximum natural slope result from edited networks.

Graphic 2 shows the sum of delay days attributable to each party, by method. Recall that in this hypothetical, responsibility for a particular delay has been assigned to a party, only the timing of the delay during the course of the project is of concern. For example, the contractor was assigned delay days for “Contractor Delay” activities and for production delays. The owner was assigned delay days for “Owner Delay” activities. One window within CPA/MIP 3.3 had two concurrently critical activities, one belonging to each party. These 6 CD were therefore designated as concurrent delay.

One very notable difference in the results of the four methods stems from the weather exclusion period. Note that in CPA/MIP 3.3 analysis, the weather exclusion period becomes a primary driver of the predicted completion date in January 2012, whereas in RTIA/MIP 3.7, the predicted completion date is driven by the weather exclusion period starting in December 2011. APAB/MIP 3.2 is not affected by the weather exclusion period, which is due to the observational nature of the method. CAB/MIP 3.9 is a modeled method, and such methods could potentially show effects of such large non-work periods; however, the test series as it was organized did not ultimately allow the CAB/MIP 3.9 analysis to do so. The implications of this will be discussed further below; however, for the purposes of Graphic 2, the delay days attributable to the effects of the weather exclusion period is kept in a separate column without apportionment to one party.

MIP	Method	Delay due to Owner	Delay due to Contractor	Concurrent Delay	Delay due to Weather Period	Total
3.2	APAB	-164	-152	-	-	-316
3.3	CPA	-114	-120	-6	-76	-316
3.7	RTIA	-165	-40	-	-111	-316
3.9	CAB	-31	-285	-	-	-316

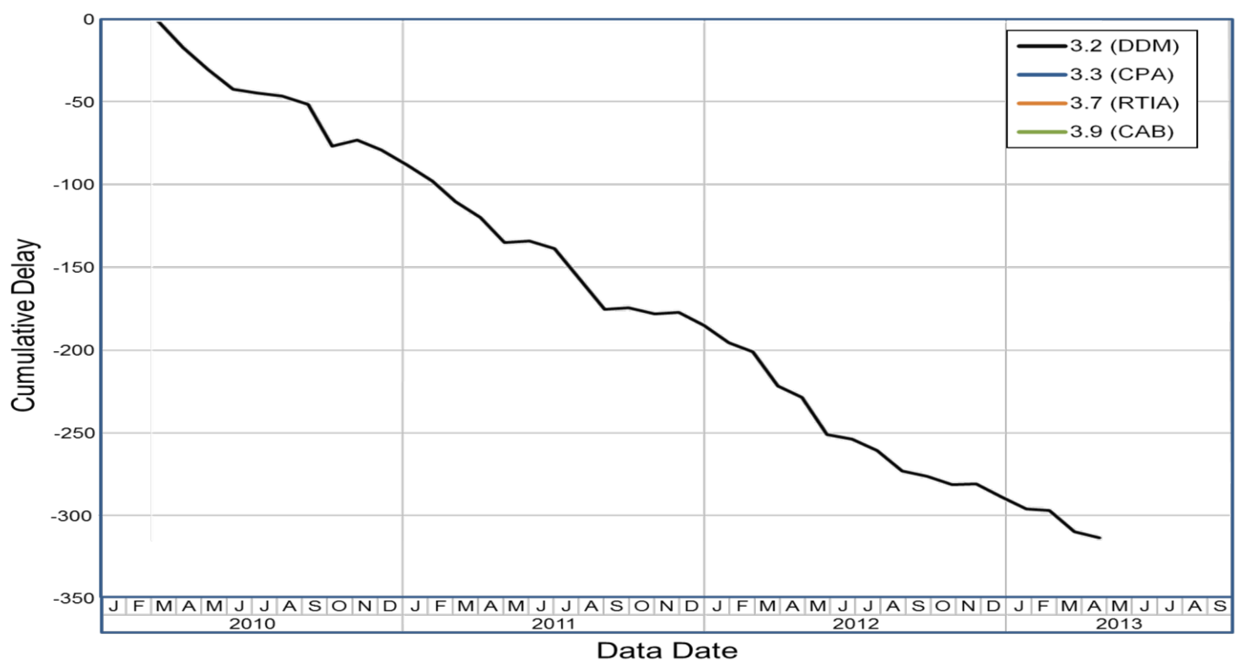
GRAPHIC 2: Delay Totals by Method

As-Planned vs. As-Built and the Daily Delay Measure/MIP 3.2:

As-Planned vs. As-Built [11] analyses compare a baseline schedule plan, consisting of one set of network logic, to the as-built state of the same network. The schedules can be compared globally, or can be broken into smaller windows that can increase the granularity and precision of delay determination. Additional mathematical analyses (such as productivity analysis, earned value analysis, or measured mile analysis) help establish the as-built critical path and apportion responsibility for specific periods of delay to specific parties – so that the analysis does not descend into the rightly rejected "total time" analysis. [2]

In its simplest implementation that borders on a "total time" methodology, the APAB/MIP 3.2 does not consider contemporaneous understanding of criticality; however, more sophisticated implementations attempt to identify the as-built critical path through a careful examination of the record. Identification of the as-built critical path can take into account contemporaneous understanding of criticality, [8] although this is not essential to the method. As a result, the DDM line on the cumulative delay graph does also not consider the contemporaneous understanding of criticality. It is not a projection of how many days ahead or behind schedule the project management team believed themselves to be at a given point in time – it is a mathematical calculation of the actual number of days of delay at the point of measurement.

The calculations for the DDM values were performed on a weekly basis for the duration of the project, and plotted on the graph in Graphic 3. The slope of the DDM line does not exceed the maximum natural slope. Given that the APAB does not recognize delays until they actually occur (no project forward delay), this is expected. As measured by the DDM, the delay accumulated during a window will not exceed the duration of that window. In other words, the slope of the DDM line will not exceed the maximum natural slope.



GRAPHIC 3: Daily Delay Measure Graph

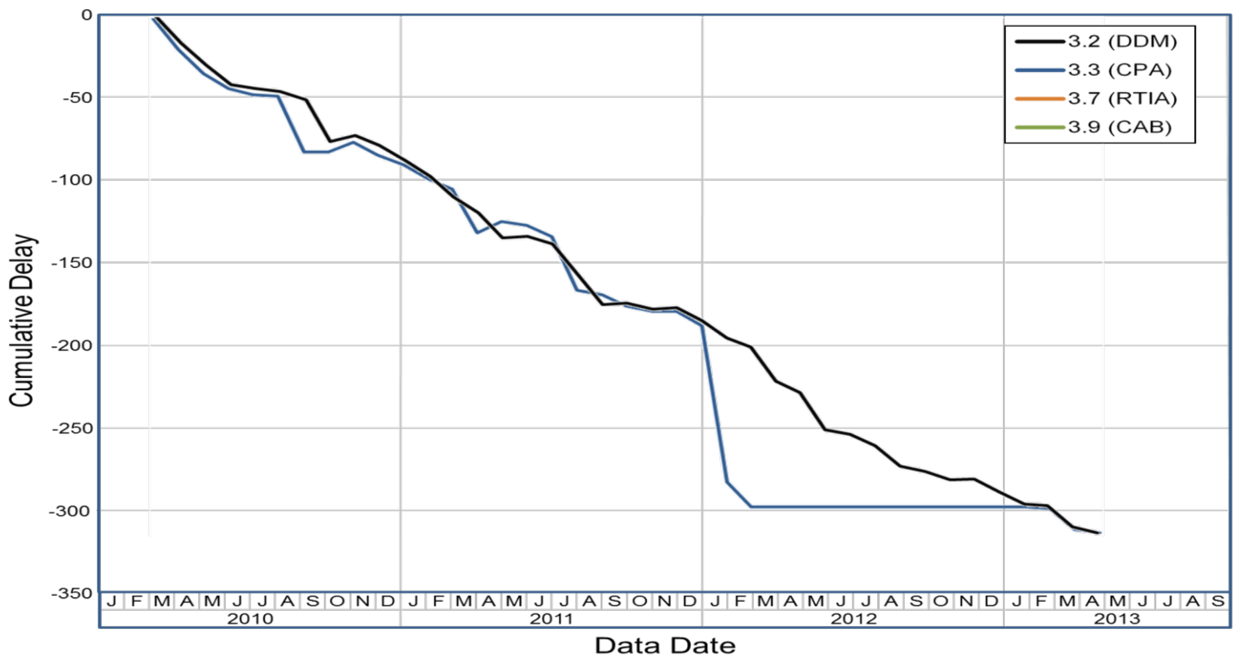
The DDM line in Graphic 3 serves as the basis of comparison for the cumulative delay lines of the other methods. Since it measures the actual delay as it occurred, it provides a useful reference point from an observational perspective against which analysts can compare the modeled methods.

Contemporaneous Period Analysis/MIP 3.3

The CPA [8], [18] uses the update schedules created during construction to reconstruct the events of the project, and thereby demonstrating the changing nature of the critical path through each of the successive updates. As project events such as progress and unforeseen conditions unfold and are reflected in the contemporaneous schedules, the effects of progress and subsequent network revisions (hopefully linked to the contractor's revisions to intended means and methods) will cause gains and losses to each schedule's predicted completion date. Additionally, subsequent schedules in the contemporaneous series will show when the critical path of the project shifts from one area to another. The size of the window to be analyzed is variable: month-to-month is common, but it is possible to make the windows more narrow (such as week-to-week) or define windows by alleged delay events.

The CPA [12] and its more complex implementation, the Bifurcated CPA, [18] rely heavily upon the contemporaneous understanding of criticality because they are using the existing schedule series to determine what the project team though was critical at the time. Note that there is a third type of Contemporaneous Period Analysis – the Recreated Contemporaneous Period Analysis [10] – which uses schedules recreated by the analyst, presumably because adequate schedules were not created contemporaneously. Since the schedules used in this analysis did not exist on the project, they could not have influenced execution. The Recreated Contemporaneous Period Analysis does not, therefore, use a contemporaneous understanding of criticality. [22]

The update schedules created for the test series were used to create the cumulative delay graph. When owner delay activities start during the update period, they were shown with their Actual Start date and a Remaining Duration proportional to the Original Duration, assuming straight-line progress across the activity. They were not used to forward-project the entirety of the delay, as is the case with RTIA/MIP 3.7. Graphic 3.4 shows this.



Graphic 4: CPA/3.3 as compared to APAB/3.2 DDM

The most notable feature of the CPA/MIP 3.3 line is that between NTP and 1-Jan-2012, it generally follows a similar path to the APAB/MIP 3.2 DDM line; however, it is also clear that the CPA/MIP 3.3 line tends to lead the DDM line by some amount. Specifically, the CPA/MIP 3.3 line accrues delay between two and 30 CD faster than the APAB/MIP 3.2 DDM line. On average, the CPA/MIP 3.3 line leads the DDM by approximately 5 CD.

This is consistent with expectations: CPA/MIP 3.3 predicts the upcoming window's delay as of that schedule update's data date, whereas the APAB/MIP 3.2 DDM line tracks actual delay as it occurs. For instance, in Graphic 4, on 1-Sep-2010 the cumulative delay values for the APAB/MIP 3.2 DDM show that the project had accumulated 51 CD of delay. On the other hand, CPA/MIP 3.3 determines that the project had accumulated 82 CD of delay as of the same date. This difference of 31 CD of delay is superficially a significant difference in the results of the two analyses; however, as of 1-Oct-2010, the APAB/MIP 3.2 DDM line shows roughly 77 CD of delay, and the CPA/MIP 3.3 CPA line continues to show 82 CD of delay. The CPA simply looked forward and predicted that in the upcoming window, there would be 82 CD of delay. The DDM does not look forward, and therefore the delay accrued over the window until the point where the two analyses are largely in agreement.

In this test series, the two analyses identify the same activities as the cause of delay during this window. The cumulative delay graphic therefore primarily assists in this window with quantification of delay associated with the specific events. However, in the event that the APAB/MIP 3.2 DDM and the CPA/MIP 3.3 determined that the ABCP was different than the contemporaneous critical path during this window, the discussion between the parties should shift to whether the CPA/MIP 3.3 is an appropriate method for the analysis.

Assume that a CPA/MIP 3.3 shows that a given activity was, as of the data date of a particular update, predicted to cause 15 CD of delay, and that the analyst performing the CPA/MIP 3.3 asserts that the predicted delay is proof of entitlement to an excusable and compensable time extension. Meanwhile, the APAB/MIP 3.2 DDM for that same window shows that a different activity drives the ABCP for that same window and caused 17 CD of delay. The quanta are roughly in line; however, the cause of delay is in dispute. The issue again becomes whether the schedule series affected the contemporaneous understanding of criticality. The analyst performing the APAB has the benefit of demonstrating what actually delayed the project; however, as previously discussed, the contemporaneous view of criticality is preferred, if it can be proven. The analyst performing the CPA/MIP 3.3 cannot simply state that the prediction showed a delay would occur; he or she should also show that the prediction affected the project management team's actions in some way (such as shifting resources to the activity perceived to be critical, or planning for accelerated work in the future). If the predicted delay existed only on the scheduler's software and never influenced the project management team's actions, then the contemporaneous understanding of criticality was not affected and the predicted delay is meaningless. In this case, the authors believe that the APAB/MIP 3.2 DDM line and its associated as built critical path causal activity are more appropriate to determine the delay for the window.

In January 2012 the CPA/MIP 3.3 line drops from a predicted delay of 185 CD to 300 CD of delay. This is due to the effects of the previously discussed weather exclusion period. This sudden drop of 115 CD is, again, a predicted delay resulting from the effects of the weather period. Note, however, that the APAB/MIP3.2 DDM continues to trend steadily downward at an average slope of approximately 8 CD/ Mo. In practical terms, the analyst performing the APAB/MIP 3.2 and relying on the DDM would say that the effects of the weather exclusion period were irrelevant: the contractor had been incapable of maintaining schedule prior to 1-Jan-2012, and the work excluded by the non-work period would not have been available for execution any earlier. In the APAB/MIP 3.2 analysis, then, the 115 CD were a result of the contractor's poor progress. In contrast, the analyst performing the CPA/MIP 3.3 would argue that owner delay activities (including differing site conditions, design changes, etc.) pushed the work into the weather exclusion period and that therefore the 115 CD were the responsibility of the owner.

In answer to the other party's charges that poor progress was the cause, the contractor could mount a defense of "pacing" of work. In other words, the contractor would allege that given his or her knowledge of the future delay brought about by the weather exclusion (linked with his contemporaneous analysis that attributed this delay to the owner), the contractor deliberately slowed production on available work so that it would be complete only just in time for the early start of the weather-affected work. Once again, however, this is an argument that rests heavily with the contractor's contemporaneous understanding of criticality. In order for this pacing argument to be legitimate, the contractor would need to show that he had this understanding of the weather delay as of 1-Jan-2012, and that he or she took actions to slow the production. Without this demonstration, it will be difficult for the owner to accept that the production delays before 1-Jan-2012, were the result of the contractor's poor productivity, whereas the production delays after1- Jan-2012, were the result of deliberate pacing. The cumulative delay graph highlights the need for proof of this contemporaneous understanding of criticality.

Therefore, for the purposes of establishing that the CPA/MIP 3.3 graph is the appropriate measurement tool and that it should supersede the other method's graph for a given period, the analyst performing the CPA/MIP 3.3 should establish the following: [25]

1. The analyst must confirm that the means and methods were accurately represented in the contemporaneous update.
2. The analyst must confirm that the schedule was used to plan and execute the project, and that the results of the CPM calculation influenced the contemporaneous understanding of criticality.

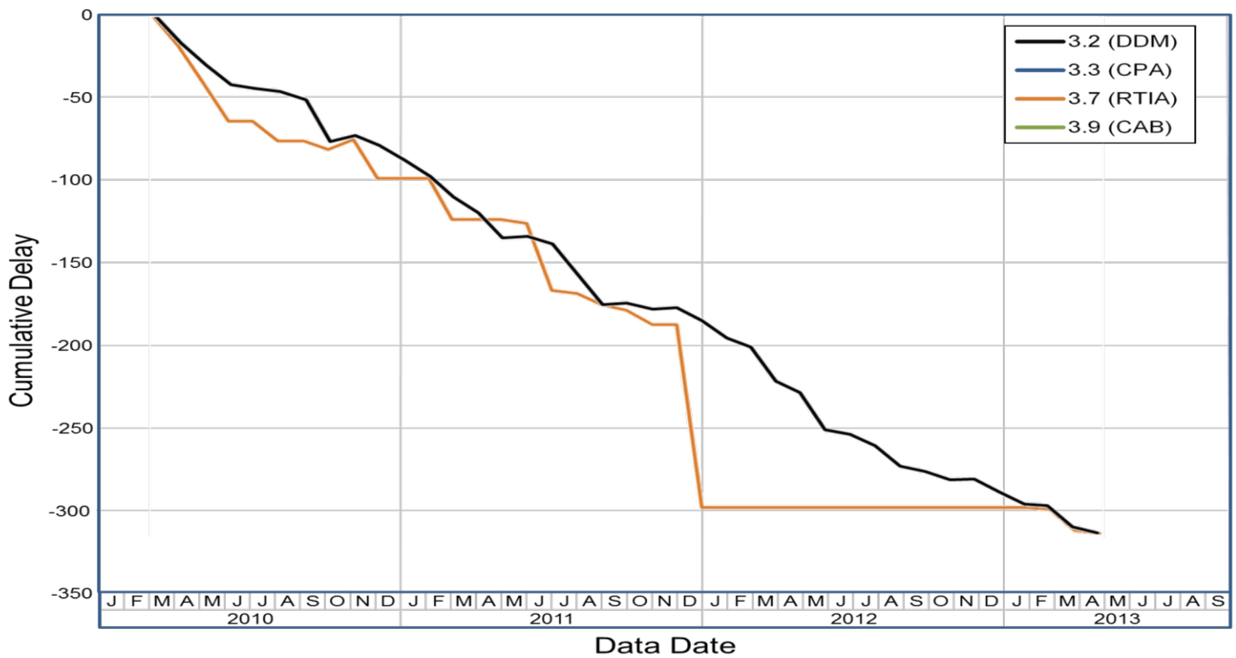
The analyst would conceivably accomplish this through review of project documentation such as meeting minutes, daily reports, and correspondence. This backup information would be essential, however, to justifying the use of a specific method's cumulative delay graph and associated causal activities.

MIP 3.7: Retrospective Time Impact Analysis

The TIA is one of the most common and widely accepted methods to analyze project delays. A TIA compares two schedules with the same data date – one schedule (the "unimpacted schedule") that represents the status of construction and the critical path just before the discovery of an event, and a second schedule (the "impacted schedule") that represents what happens to the critical path and the predicted completion date once the delay event occurs. The event, administrative resolution time, and added work necessary to return to original contract work are represented in the impacted schedule through the addition of a fragnet consisting of representative activities and logic. The comparison of the predicted completion dates of these two schedules (before and after the fragnet insertion) determines whether there is entitlement to a time extension.

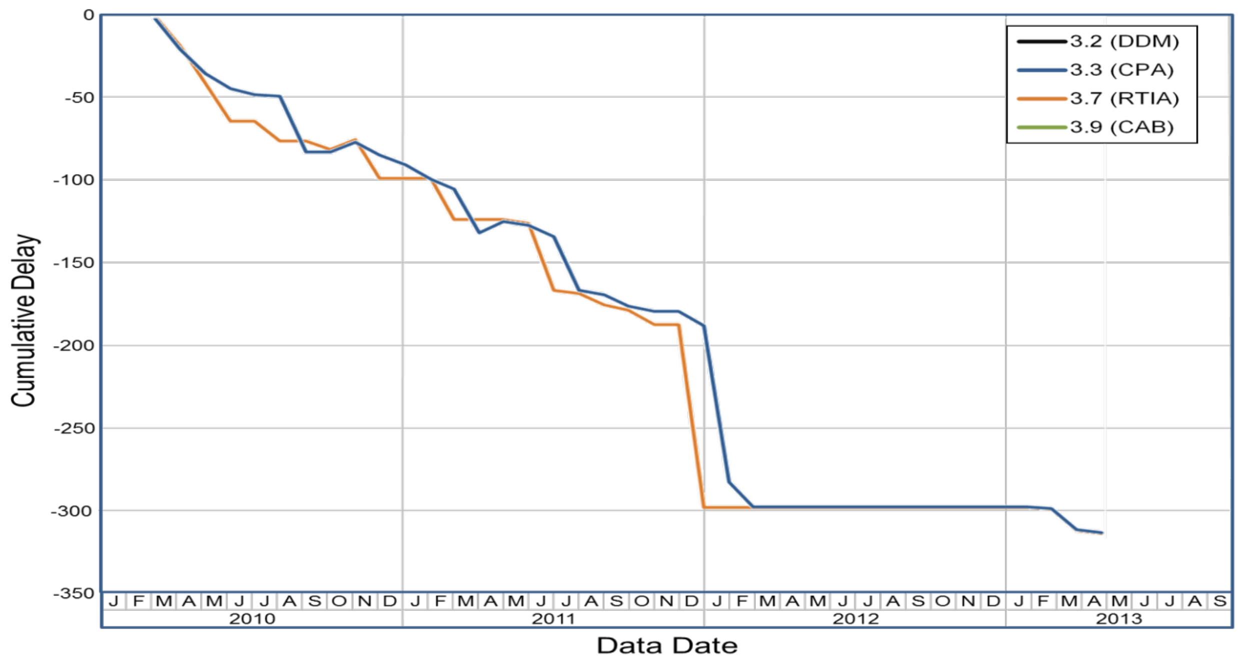
Though widely popular and commonly used, one important aspect of the TIA is also widely overlooked: the timing of the analysis. If a TIA is conducted before the added work is performed, it is a *Prospective* TIA. [3] A Prospective TIA is an essential tool for the project scheduler to determine the likely impacts of changed conditions on a project and is often included as a requirement in the contract as a prerequisite for granting a time extension. When the change management plan on a project is working properly, a Prospective TIA is associated with a bilateral modification that adds the time (and money) to the contract necessary to compensate the contractor for the change. [15]

However, as discussed, the forensic analyst is constrained by the fact that he or she joins the project after project completion. Therefore, any TIA that is performed is done after the added work has been completed, and is therefore a *Retrospective* TIA. There is some controversy about the use of Retrospective TIAs due to the potential for manipulation and the fact that modeling events retrospectively allows selective modeling of only one party's alleged delays while excluding others. [17] A Retrospective TIA that only models owner delays will tend to conclude that only the owner was responsible for the delays, whereas one which only models contractor delays will show the opposite. This can lead to an imbalanced view of responsibility of delays. Despite this, it is conceivably possible to perform an effective Retrospective TIA. In selecting this method, however, the analyst is abandoning the contemporaneous understating of criticality, because this technique is creating new schedules, not used on the project, while modeling actual events retrospectively.



Graphic 5: RTIA/MIP 3.7 as compared to APAB/MIP 3.2 DDM

The RTIA/MIP 3.7 line tends to lead the CPA/MIP 3.2 DDM line in a manner similar, yet more pronounced, than did the CPA/MIP 3.3 line. The RTIA/MIP 3.7 RTIA/MIP 3.7 line leads by an average of approximately 13 CD. Again, this lead is related to the fact that the RTIA/MIP 3.7 is predicting delay rather than measuring actual delay; however, in contrast to CPA/MIP 3.3, the RTIA/MIP 3.7 is predicting delay in inserted fragnets as well as in the original CPM network. To better understand the differences between the two, refer to Graphic 6.

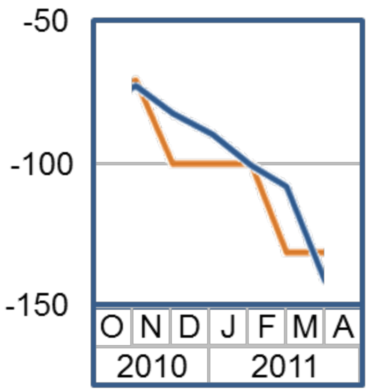


GRAPHIC 6: RTIA/MIP 3.7 as compared to CPA/MIP 3.3

The RTIA leads the CPA/MIP 3.3 line by an average of roughly 7 CD. In addition, note that in Graphic 2, the number of days assigned to the contractor (40 CD of delay) is much lower than in the other methods. In the CPA/MIP 3.3 analysis, the apportioned delay between owner and contractor was 51% to 49%; in RTIA/MIP 3.7 RTIA/MIP 3.7, the apportioned delay split was 71% to 17%. The contractor tends to receive a lower apportionment of delay days in methods that forward-project delays associated only with the owner. In other words, if the fragnets inserted into an RTIA are always representative of the other party's alleged delays, then the analysis will tend to show that the other party is responsible for most of the delays. For this reason, it is not good practice to only model one party's delays. However, there are conceivably occasions when such an analysis could be appropriate, and those would be times when the inserted fragnets were representative of the contemporaneous understanding of criticality.

CPA/MIP 3.3 (including the related bifurcated CPA/MIP 3.4) and RTIA/MIP 3.7, each propose a forward-looking modeled analysis wherein the contemporaneous understanding of criticality is assumed, but must be proven. However, CPA/MIP 3.3 only assumes that the unimpacted CPM network influenced this understanding, while RTIA/MIP 3.7 assumes that both the fragnet and the CPM network were influential. Of course, this is not always accurate. If the fragnet was contemporaneously proposed and established, it is likely that the use of this fragnet in a RTIA/MIP 3.7 is correct in its assumption that the party inserting the fragnet had a contemporaneous understanding of criticality as projected by the fragnet and schedule recalculation. This assertion could of course be disputed or refuted by the other party. However, if the fragnets are created after the fact and were never considered by the project management team during project execution, then it is unlikely that the RTIA/MIP 3.7 in this case is representing any contemporaneous understanding of criticality. In other words, it pretends that the on-site management would see future events as the re-calculated after-the-fact schedule depicts them.

The impact is seen in the cumulative delay graphs in the way that more delay accrues earlier in the RTIA/MIP 3.7 graph. Graphic 7 shows the MIP 3.3 and the MIP 3.7 graph for the period between November 2010 to April 2011.



DD	3.3 Delay	3.7 Delay
11/1/2010	-76	-76
12/1/2010	-84	-100
1/1/2011	-90	-100
2/1/2011	-99	-100
3/1/2011	-105	-125
4/1/2011	-132	-125

GRAPHIC 7: RTIA/MIP 3.7 as compared to CPA/MIP 3.3 for November 2010 to April 2011

Both cumulative graphs begin at the same point of delay, each calculating that the project was 76 CD behind schedule as of 1-Nov-2010. However, at the start of December 2010, RTIA/MIP 3.7 calculates that the project is 100 CD behind schedule, compared to only 84 CD for CPA/MIP 3.3. The RTIA/MIP 3.7 cumulative delay graph stays flat from 1-Dec-2010 to 1-Feb-2011, at which point it begins to accumulate delay again. The authors reviewed the test schedules to determine what the driving activities were during this window, and determined that in the 1-Nov-2010 update schedule, the RTIA/MIP 3.7 included a fragnet representing a differing site condition. The insertion of the fragnet caused the sudden loss of 24 CD during the month of November. In comparison, the CPA/MIP 3.3 line identifies only an 8 CD delay during the same month, related to poor contractor production.

This dichotomy reveals the heart of many disputes. One party uses a modeled technique that “proves” that the critical path ran through an owner-caused differing site condition, while the other party’s modeled technique “proves” that the problem was actually sustained poor production. Particularly if the contractor is using the RTIA/MIP 3.7 and the owner is using the CPA/MPI 3.3, this argument can go on without resolution. However, the cumulative delay graph highlights the timing of the delay accrual, which relates directly to the contemporaneous understanding of criticality. The RTIA/MIP 3.7 effectively alleges that, as of 1-Nov-2010 (or reasonably close to that date) the contractor had identified the differing site condition, had estimated the duration of time necessary to overcome the change in order to return to contract work, and had perceived that the predicted completion date was delayed by 24 CD as a result. These are the facts that must be proven to establish the propriety of the RTIA/MIP 3.7’s conclusions; without this, it is very easy to foresee scenarios when one party’s analyst simply forward-impacts a CPM model with fragnets of the other party's delays until the analyst's client apparently bears no responsibility for any delay. The RTIA/MIP 3.7 line will simply stair-step down through the project duration, claiming that delay accrued earlier than it actually did and was always the responsibility of the other party.

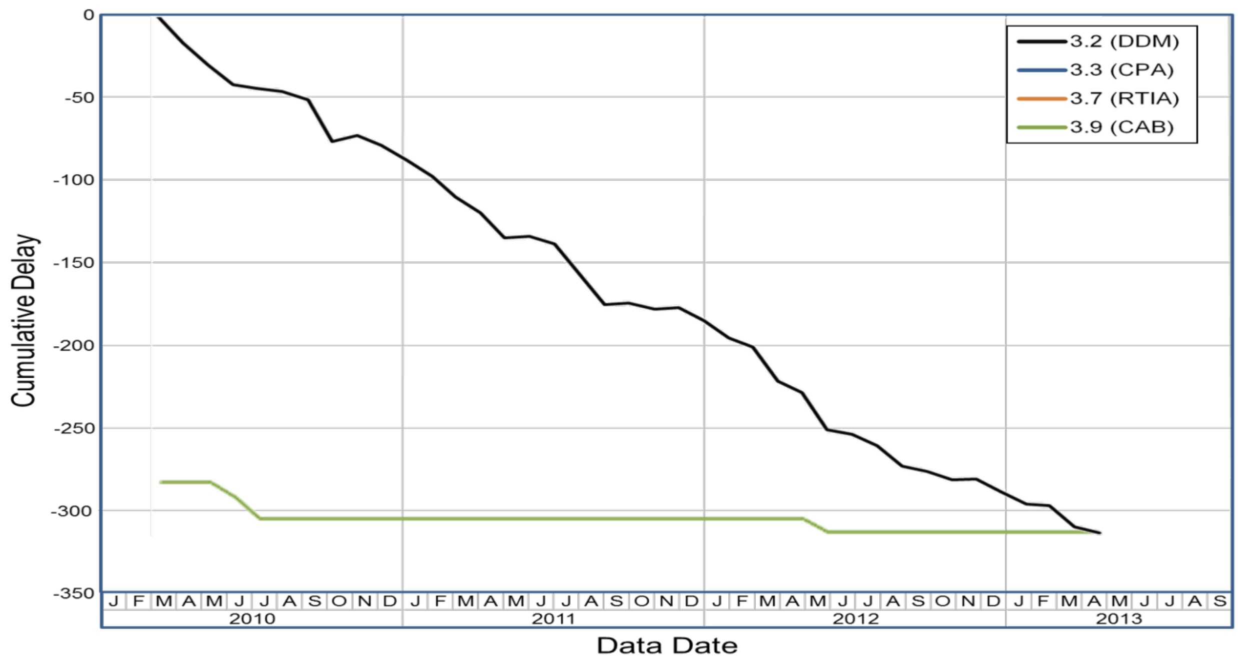
Therefore, for the purposes of establishing that the RTIA/MIP 3.7 graph is the appropriate measurement tool and that it should supersede the other method's graph for a given period, the analyst performing the RTIA/MIP 3.7 should establish the following: [25]

1. The analyst must confirm that the means and methods were accurately represented in the contemporaneous update.
2. The analyst must confirm that the schedule was used to plan and execute the project, and that the results of the CPM calculation influenced the contemporaneous understanding of criticality.
3. The analyst must also confirm that as of the Data Date of the schedule (or reasonably soon thereafter) the project management team became aware of the issue modeled in the fragnet, that they impacted the schedule with the fragnet, and that the resulting shift in the CP and later predicted completion date influenced the project management team's contemporaneous understanding of criticality.
4. The analyst should also be prepared to discuss whether there was contemporaneous pacing.

MIP 3.9: Collapsed As-Built

The Collapsed As-Built method recreates a CPM model of the as-built schedule by creating logic and durations that reflect the apparent logic that drove the work and the actual dates on which the work was performed. The analyst then dissolves selected delay activities recalculates the schedule in order to show what would have happened had a certain event not taken place. The Collapsed As-Built method can either be performed in a single step (deleting all alleged delay activities at once) or in multiple steps (removing one activity at a time and recalculating after each deletion). A conceptual advantage to the Collapsed As-Built method is that the as-built schedule contains both parties' delays, so if the analyst removes only one party's delays from the schedule, the other party's delays are still present. In other words, the Collapsed As-Built naturally considers both parties' delays. Because this technique involves creating a series of CPM schedules which were not used on the project, it does not rely upon the contemporaneous understanding of criticality.

For this analysis, the authors started with the test series' Collapsible As-Built Schedule, and dissolved each owner delay activity in turn, beginning with the activity with the latest finish date and moving backwards. After each dissolution, the schedule is recalculated and the change in the predicted completion date was recorded. As shown in Graphic 3, after all the owner delay activities were dissolved, the predicted completion date had shifted 31 CD earlier than the actual finish. As such, these 31 CD were assigned to the owner, while the remaining 285 CD were assigned to the contractor.



GRAPHIC 8 : CAB/MIP 3.9 as compared to APAB/MIP 3.2 (DDM)

The cumulative delay graph for CAB/MIP 3.9's analysis is clearly the most divergent from the APAB/MIP 3.2 DDM line. This is understandable in terms of the fact that the method is attempting to account for both parties' delays by deleting only one party's and leaving the others in the schedule series. This runs counter to RTIA/MIP 3.7, in that with the RTIA the additive modeling of, for instance, the owner's delays has a tendency to mask the contractor's. In the CAB, the contractor's delays remain after the stepped deletion of the owner's delay activities. The cumulative delay graph for RTIA/MIP 3.7 therefore includes delays by both parties, while CAB/MIP 3.9 depicts only one party's delays.

The conclusion that could be drawn from the CAB analysis is that, but for the delays of the owner, the contractor would only have finished 31 CD earlier. Note that the weather exclusion period was not regained during the dissolution of the owner delay activities; therefore, it is possible to conclude that regardless of the owner's delays, the contractor would have encountered the weather exclusion period's jump in predicted completion date on its own. This explains why the weather exclusion period days are assigned to the contractor in Graphic 3.

The CAB measures delay in a significantly different manner than the other three methods. First, it does not attempt to start at the NTP date, where there were zero days of delay accrued, and work forward through each window. Instead, it analyzes the project in reverse, starting with the actual number of delay days accrued. Second, the method is designed to specifically leave behind one party's delays. As a result, the MIP 3.9 CAB line will never return to zero. The authors have concluded that at this point the only technique for reconciling the CAB with the other methods would be to perform the CAB/MIP 3.9 twice, once excluding the owner's delays and then excluding the contractor's delays.

Conclusions

The use of the cumulative delay graph can be a useful tool in reconciling the apparently different results of methods. It is particularly useful when used as part of a larger process of putting the results of the methods into a common format and a collaborative effort between the parties to establish periods of similarity and differences. The cumulative delay graph will aid in establishing when delays accrued; it will not, however, resolve disputes where the causal activity is agreed upon but the underlying reason for delay is at issue.

Generally speaking, the APAB/MIP 3.2 DDM line establishes when the delay actually occurred. The CPA/MIP 3.3 line tends to show that delay accrues slightly earlier than the APAB/MIP 3.2 DDM line, because the CPA/MIP 3.2 is calculating the delay to the predicted completion date based on the unedited CPM network alone. The RTIA/MIP 3.7 tends to show that delay accrues earlier than the CPA/MIP 3.3, because the RTIA/MIP 3.7 is calculating delay to the predicted completion date based on the CPM network as impacted by fragnets. A longer fragnet will tend to claim more delay earlier.

The cumulative delay graph highlights when delay either actually occurred, as in the APAB/CIP 3.2 DDM line, or when it was perceived by the parties to have occurred, as with the CPA/MIP 3.2 and the RTIA/MIP 3.7. In order to prove that this perception represents a valid means for viewing project delay, analysts should establish whether the contemporaneous understanding of criticality can or cannot be assumed. However, it is still possible to compare an analysis which does assume and one which does not (such as MIP 3.2 to MIP 3.3, which is particularly effective). But in a situation where the contemporaneous understanding of criticality cannot be established, it may be necessary to eliminate certain methods from consideration.

Finally, analyses developed outside of standards of good practice will likely show radically different results on this chart. Therefore, the use of this technique can help refute the technical implementation of the opposing expert’s analysis.

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The seminal text explains the primacy of understanding the contemporaneous understanding of criticality within a forensic delay analysis: "*Delays are best evaluated on a chronological and cumulative basis, taking into account the status (and critical path[s]) of the project at the time of the delay in question. With this method and protocol, all parties on the project live with the events, actions, and 'sins' of the past.*"

21 In a CPA, wide windows (greater than a month) are undesirable. One of the major benefits of a CPA is to track the movement of the critical path, which is known to be variable based on progress and evolving means and methods. Using wide windows opens the possibility that the critical path will undergo multiple shifts during the window and will not be cataloged by the analyst. This would allow delays to be misallocated to specific events and parties. A month-long window is usually the maximum width of a window because of the fact that the pay applications – a useful back-check on the state of progress to date – are generally submitted on a monthly basis.

22 MIP 3.5 allows for a wide range of after-the-fact reconstruction. If only minor adjustments to the contemporaneous schedule updates are made, they may actually reflect the contemporaneous understanding of criticality.

23

23 Regarding the need to avoid adversarial interests in the use of schedules developed under an adversarial relationship, the authors state: "In Nello L. Teer Co., the Board found that the usefulness of a CPM schedule tends to become suspect when the contractor and the owner have developed adversarial interests. The Board noted that there are too many variable subject to manipulation to permit acceptance of the conclusions of CPM consultants in such circumstances. The Board also noted that this is not to say that the CPM analyses are not to be used in connection with contract claims. On the contrary, they often are the most feasible way to determine complicated delay issues. However, the Board must have confidence in the credibility of the consultants and the cogency of their presentations. In connection with the testimony of Nello Teer's scheduling expert, the Board noted that the expert continually expressed conclusions as to construction management that were beyond any expertise that the Board considered the expert to have demonstrated."

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25 These recommendations are made to be performed in concert with the recommendations of RP 29R-03's Section 2 on source validation.