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July/August 2014

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### BY CPM OUT-OF-SEQUENCE METHODOLOGY

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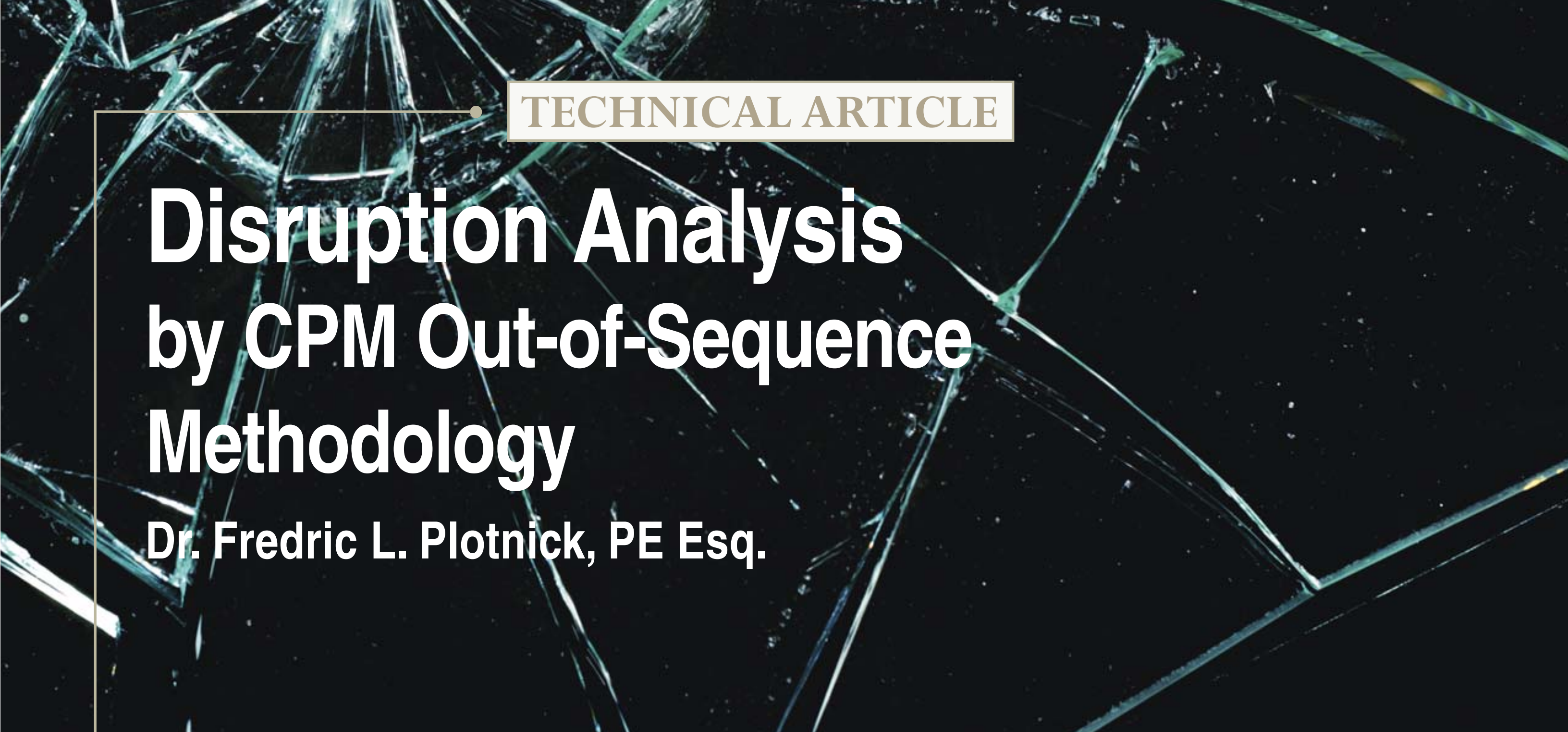

TECHNICAL ARTICLE

# Disruption Analysis by CPM Out-of-Sequence Methodology

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**Abstract:** Delay to an activity may not lead to delay of the project. However, such delay may lead to a disruption to the contractor's anticipated means and methods and be the basis for a claim. Delays imposed upon many activities may also lead to a resource driven delay to the project. This article will address a means to determine the costs of disruption at the activity level and to analyze the cumulative impact to cost and schedule at the project level. This analysis may then be compared to the more traditional methods of measurement of impact of disruption, such as the measured mile approach to determine loss of productivity, and other "big picture" analyses. This article was first presented as CDR.1278 at the 2013 AACE International Annual Meeting in Washington, DC.

**Key Words:** Cost, CPM, cumulative impact, measured-mile, and delay

The term "delay" has a special meaning to a scheduler. Activities are not subject to "delay," but rather to "disruption." If the disruption is to an activity that is on the current critical path of the project at the time the disruption occurs, then the project is subjected to a delay.

However, project correspondence and conversation among field personnel do not normally make such a distinction. Even a scheduler may say, "the concrete pour was delayed by inclement weather." The fact is that most of the "delays" on a project, even the ones most subject to dispute, do not delay the project. Some of the disruptions directly impact an activity that is currently upon the critical path. Some disruptions have an indirect impact, such as an emergency extra work order that diverts resources from an activity on the critical path. The vast majority of disruptions do not directly or indirectly cause delay. However, disruptions do have a cost to the project.

The plan of the as-planned logic network must be that of person (or persons) directing the work to be performed. This plan may be one of many possible plans, but it was the one chosen. The selection was based upon both the assumptions recorded and unreported by the scheduler, to be the most efficient in terms of time and cost. The project manager may choose to work on the project from the north to the south or vice versa. It may be presumed that the choice was not random and a disruption forcing a reversal will have some cost, even if only 15-cents.

## Traditional Methodologies

Traditional methodologies for measuring the cost impact of disruptions are much like those for measurement of delay prior to the advent of CPM. Often, a blunderbuss of alleged causative factors (deemed the responsibility of the "other" side) leading to disruptions is fired against a chart indicating planned versus actual costs. The defense is often the firing of a similar blunderbuss filled with the alleged causative factors deemed the responsibility of the initial claimant. Substitute an as-planned versus as-built bar chart for the cost curves and we have a pre-CPM delay analysis. A more refined methodology is to measure the difference between planned and actual productivity and costs during a period of calm (called the "measured mile") and compare it to the same difference during a period of disruption. Obviously, the circumstantial evidence of this analysis is greater, but still lacks a firm cause and effect relationship.

## Analysis of Claim of Loss of Productivity via Measured Mile Methodology

The use of the Measured Mile methodology to support a claim of loss of productivity has been accepted on numerous occasions [2]. Authorship of the Measured Mile methodology is often laid to Dwight A. Zink, who discussed this in the April

1986 edition of the AACE **Cost Engineering** journal [6]. The conclusion to his article states:

> "The 'measured mile' approach to isolating the disruption costs of acceleration is generally accepted by the courts as being a reasonable way of determining the damages incurred over and above those which should have been expected. However, the size of the sample must also be reasonable—i.e., extrapolating two percent of progress into 80 percent of expected costs would hardly be reasonable."

Another definitive article on this methodology was written by Michael Finke, PE, *Statistical Evaluations of Measured Mile Productivity Claims*, published December 1998 in the AACE **Cost Engineering** journal [7]. (Mr. Finke, was also an attorney admitted before the Georgia Bar. At the time of his death in 2002, he reportedly was actively working on his doctorate.) Proceedings of the 2008 AACE International Annual Meeting also cites an earlier work by Mr. Finke in the paper associated with session CDR.07 [4]:

> Unfortunately, many claimants and their experts do not put enough emphasis on proving causation of lost productivity. "Because of the widely accepted need to rely on expert opinion when presenting loss of productivity claims, there seems to be an unfortunate tendency for such claims to minimize the use of facts and maximize the use of opinions. This is typically done by employing approximate or generalized analyses and theories and making leaps of faith from liability to quantum, thereby glossing over the causation element." [Finke, Claims for Construction Productivity Losses, 26 Pub. Cont. L.J. 311, 334 (1997)][8]

The 2008 CDR.07 [4] paper continues with additional insights relevant to review of an analysis using the Measured Mile Methodology. Most importantly is that the methodology is to quantify damages and does not, of itself, relate to proof that damages are warranted. Thus:

> "The most appropriate use of a measured mile comparison ... assumes that the contractor has already proven, by other means, that owner-liability exists (e.g., formal or constructive change orders), that the type of damage being alleged actually occurred."

The introduction of another proceedings of the 2008 AACE International Annual Meeting, CDR.05, *The Measured Mile – a Better Way of Using an Old Tool*, by Glen R. Palmer, PSP [3], leads us to the issue of the, "level of detail," associated the Measured Mile analysis:

> "The 'measured mile' analysis is usually thought of as the industry's best approach for analyzing and quantifying productivity disruptions. Most productivity experts agree that the major obstacle in performing this kind of analysis is validating that the work analyzed, in both the baseline and impacted periods, is comparable [5]."

The second most important consideration in performing a measured mile analysis is the level of detail of which both worker hours and work progress are tracked. The productivity of above ground large bore pipe can only be evaluated if both the expended worker hours and installation progress are tracked at that level of detail or lower. If, for example, work progress for above ground large bore pipe is tracked, but the expended worker hours for all above ground piping work is lumped together, then that would make it invalid to perform a measured mile analysis at the above ground large bore pipe level of detail.

The level of detail espoused in this article is the CPM activity. The CPM activity is defined as:

> "...a set of instructions, given to a competent foreman, who is then expected to complete such without further supervision or interaction

1. "Activity started before its predecessor finished."— used to note actual dates reported this period may indicate problem within this period.
2. "Activity started, predecessor has not finished."—used for FS and FF relationships, with or without lag.
3. "Activity started before its predecessor's lag would allow."—used for FS and SS relationships with lag.
4. "Activity started, predecessor has not started."—used for SS relationships, with or without lag.
5. "Activity finished, predecessor has not finished."—used for FF relationships, with or without lag.
6. "Activity finished before its predecessor's lag would allow."—used for FF relationships with lag.
7. "Activity started too early to allow it to finish on or after its predecessor's finish."— used for FF relationships without lag.
8. "Activity started too early to allow it to finish after the expiration of its predecessor's lag."—used for FF relationships with lag.

**Figure 1—Types of Work Being Performed Out-of-Sequence**

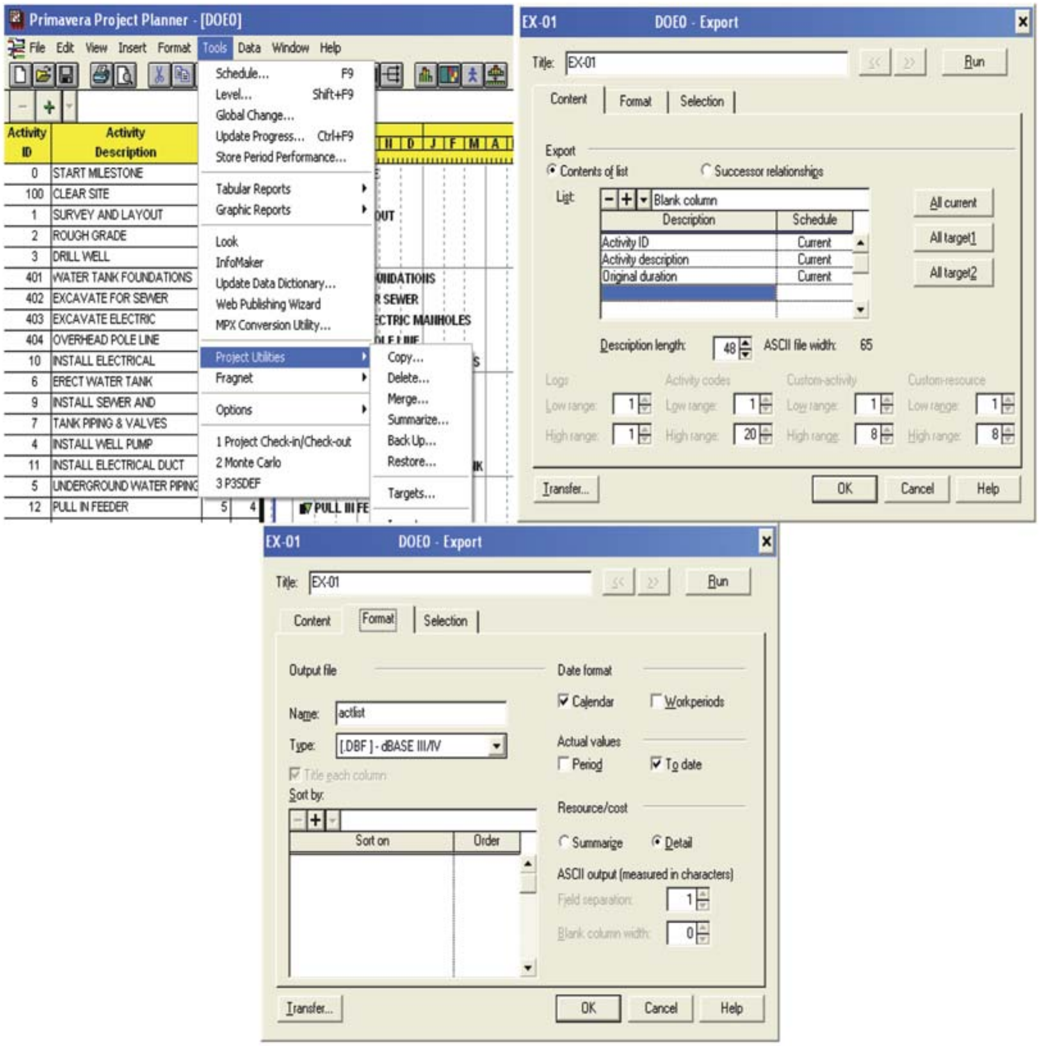


**Figure 2—Oracle Primavera P3 Export Command to Send Data to ACTLIST.dbf**

with other than his own subordinates." [1]

The level of detail for planned expenditure of resources (and for this purpose especially labor) begins at the activity. If the number of planned worker-hours is provided, this perhaps provides the best data. If only the duration and a crew designation are provided, one intermediate calculation needs to be made. If only the duration, research into the size and composition of labor envisioned may be required.

The level of detail for an actual expenditure of resources also should begin at the activity. Timesheets are typically kept at the foreman level, and if not, additional research should allow a determination of which craftspersons worked under the supervision of which foremen. If the size or composition of crews differ between that upon which durations of the plan are based, questions or adjustments may be indicated. A crew, working under the direction one foreman, rarely works on more than two CPM activities in one day. The transition from one activity to the next indicates either 100% completion of the first activity or disruption of some sort.

While a changed condition (being somewhat more than a "disruption") may increase the difficulty or productive performance of a specific activity, such is usually well recorded and may be addressed by a proper change order request. While it is possible for a crew to be "disrupted" in a manner to cause loss of productivity for a portion of a day and yet not be re-assigned to another activity on even a temporary basis, this will rarely occur day after day, and may also be addressed by a proper change order request. But, where a disruption occurs that sends a crew to another activity before the instant activity is complete, either for a day, until the second activity is complete, or for an indefinite period of time, we have a situation where the total cost of the disruption cannot be based upon merely the loss of performance on the instant activity, but also on the second and perhaps many activities.

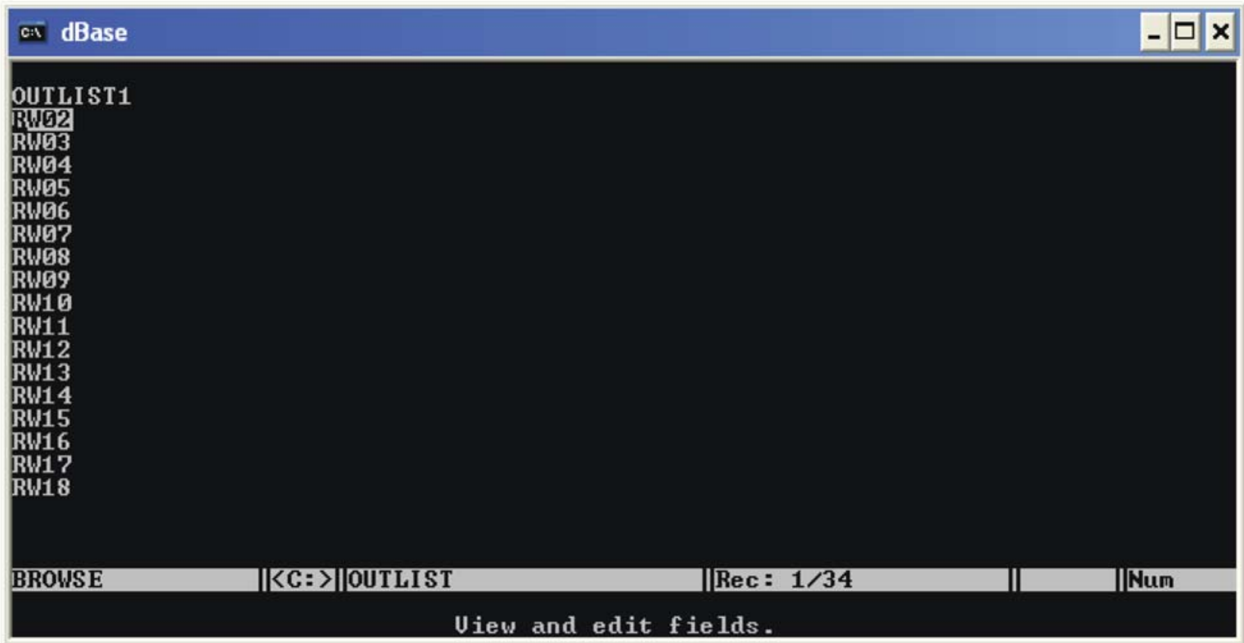


**Figure 3—Listing of Updates or Windows for Which a P3 Diagnostic Was Run**

This is the evil that has often been addressed by claims based upon total cost, or more recently upon the Measured Mile approach. It is here suggested that this issue be addressed at the activity level, rather than by total or summary methodologies.

**Proposed CPM Out-of-Sequence Methodology**

Use of the as-planned logic network adds a great deal of objectivity and reproducibility to the disruption analysis. Relating to the previous work of Zink, Finke, and others, there is a need to show a disruption and thus support an actual or constructive change order. The work of Palmer and others convey the importance of determining an appropriate level of detail; this article suggests that level be an CPM activity.

Obviously, project records of actual costs are never complete enough for the lawyers and forensic consultants, and even if they were, there is always the question of the accuracy of the initial estimates (cost and time) for the activities disrupted. However, like the value of CPM in breaking down large "ballpark" estimates of time into estimates of discrete activities—some high, some low—that cumulatively are more accurate, a similar value is imparted by the CPM relating to the estimated costs of discrete activities and the costs of disruption.

If masonry on the upper level of a two-story structure is stopped while the owner determines if he/she desires a larger or smaller window opening, it is clear that there will be some additional cost in remobilization and ramping up to speed after a restart; and if the scaffolding is left standing, there will be costs associated with the rental of the scaffold. If the scaffolding is removed to permit other trades to have access to the interior of the building (thus working out-of-sequence from the as-planned logic), there will be the additional costs of removal and re-erection. There may also be additional costs of less-than-complete access by the other trades working around stacks of block, which is, hopefully (but is not guaranteed), less than the double handling of the mason completely clearing the area. Although the quantifying of such costs may still be an estimate, the use of the measured mile approach at the activity or task level is less subject to variation and dispute than for entire areas or time periods of the project.

A project manager who is involved in the preparation of the original as-planned logic network will truly attempt to meet that schedule. One of the finest compliments given to a scheduler is when, after all the work of preparing the CPM is completed, the project manager says, "that is exactly the way I intended to build the project. What did I need you for?" If a project manager encounters a disruption that can freeze the project in its tracks, he/she may attempt to work around it. However, the project manager is certainly hoping to minimize the distortion to the "most efficient plan" and intends to return to the plan as soon as practicable. Only on the worst of projects, where the project manager is constantly running into roadblocks to the plan and even to the workarounds put in place, may the plan be abandoned and resources assigned wherever there appears to be a task to perform without interruption.

Thus, it is possible to track the disruptions to the project by analysis of progress of work performed out-of-sequence from time period to time period. Building upon the Windows

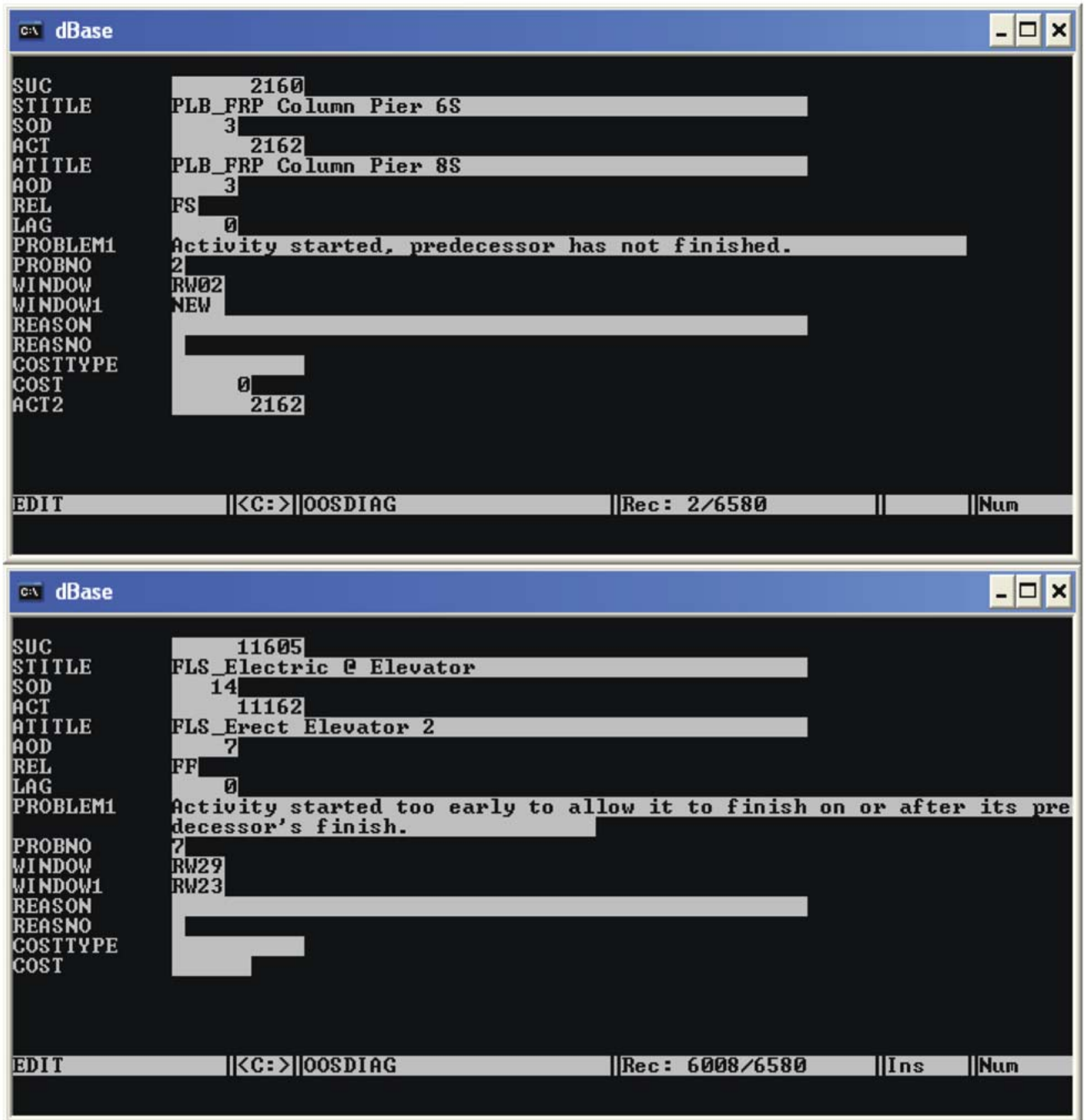


**Figure 4—Provides Two Disruptions Documented by the Out-of-Sequence Report**

methodology discussed in **AACE Recommended Practice 29R-03**, *Forensic Schedule Analysis*, the scheduler should note the instances of new and continuing work performed out-of-sequence for each statusing or update. As noted in the Windows methodology, the data dates for such updates may be a function of major causative factors, or may be periodic, if the number of causative factors makes such an exercise unwieldy.

Primavera's P3 Project Planner software's schedule diagnostic is an excellent tool for such an analysis. Each time an activity is started or finished out-of-sequence, it is reported. P3's diagnostic distinguishes between eight types of work being performed out-of-sequence (see figure 1). A similar diagnostic is provided in P6, but unfortunately focuses more on whether entered data meets the needs of enterprise coding systems than on the technical quality of the plan behind the calculated schedule.

The diagnostic allows the scheduler to distinguish between work performed out-of-sequence that may either indicate a crew getting a head start on the next activity, or the start of a disruption, ("Activity started, predecessor has not finished") from that more clearly indicating a lingering obstruction. ("Activity finished, predecessor has not finished"). Not included in the Primavera diagnostic,

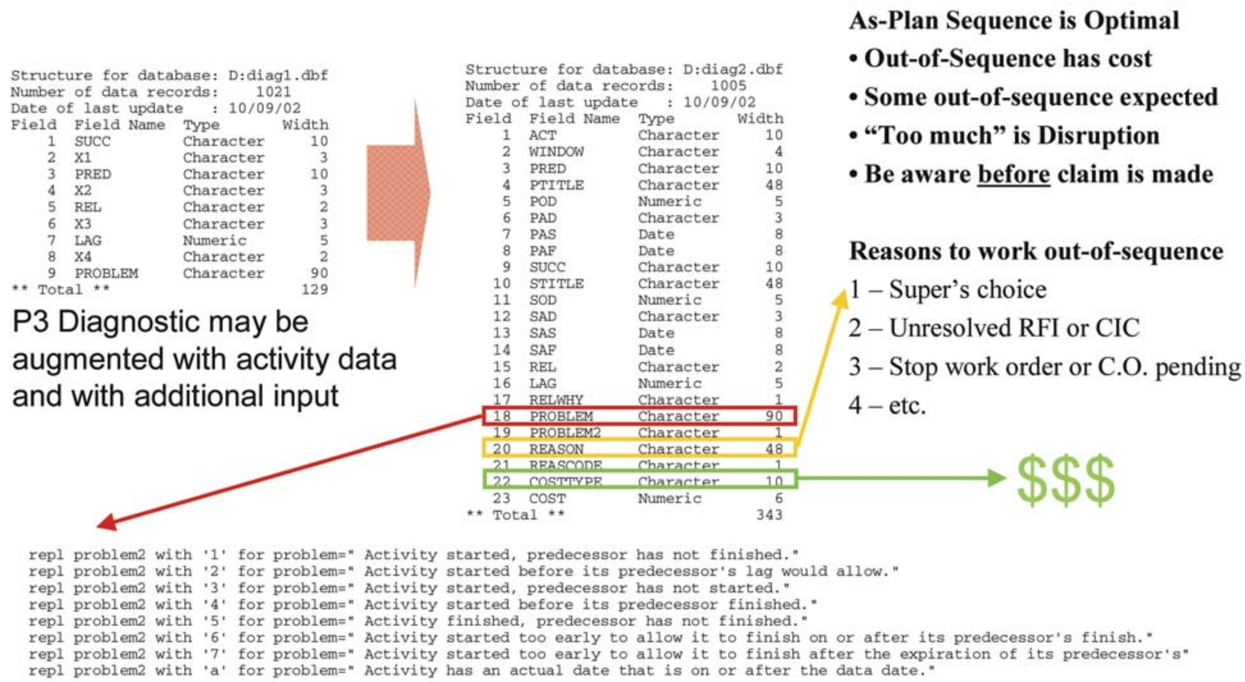


**Figure 5—Summary Depiction of Out-of-Sequence Methodology of Disruption Analysis**

but of potential use might be a code for "Activity finished, predecessor not started" to distinguish between disruptions that skip to the next activity when progress on a started activity is obstructed from those when an activity in a planned sequence is skipped over entirely. Similarly, the code "Activity finished, predecessor has not finished" is not issued by the P3 diagnostic for breaching a FS relationship, although it might be useful for this application.

At this point, the reason for each instance of out-of-sequence performance may now be noted. Reasons can range from "superintendent's choice," or "equipment failure," to "change in condition discovered," to "stop work order issued," to "unresolved RFI," to "C.O. pending," to "too much mud, sent crew elsewhere." Determining the party responsible for each cause would be next.

If a log record (of the reason why a planned activity was not started, or was started and was then stopped) was not kept, a detail review of the daily diaries of the project may be required to determine the cause of the disruption. This process is greatly aided if the previously prepared list of causative factors includes all, and not only the most noteworthy, incidents that have occurred. Having determined a disruption and its impact to a specific activity or flow of activities, a cost can be assigned to the specific disruption. This may involve some level of subjectivity, but the level of disagreements should be small if each side renders an opinion in good faith for these small amounts. After all, remobilization of a drill rig for one piling initially skipped because of the discovery of an undocumented pipe is unlikely to cost either $100,000 or zero.

A contractor can expect some reasonable level of disruption as this is expected in any endeavor. However, if the level of disruption tips that of reasonableness, the total of the impact of "1000 bee stings" begins to look like real money. Where the totals of the disruption analysis are similar to that of traditional methodologies, a very strong case can be made for compensation.

**Example of Software to Automate Out-of-Sequence Disruption Diagnostic**

Collecting the information from the various diagnostics may be a tedious project in of itself. Fortunately, relief from this tedium is what the computer was invented to do. A software program to implement this analysis is provided electronically as "Additional Content" for this article. To view this, please visit www.aacei,org and look for te online content button. This program, written several years ago for demonstration of disruption and cost thereof, was programmed in dBase III+, an "ancient" software product running is DOS (that being before release of Microsoft Windows). However, it still runs, and may be converted by readers of this article to Microsoft Access or other software product. (Please, if you do this, send the author a copy).

As annotated in the program listing, the first step is to copy a full list of activities from the project CPM, including Activity ID, title and duration, to a file named ACTLIST.dbf. In P3, this may be done via the Export Command as depicted in figure 2. The next step is to run Schedule Command for each update impacted by a claimed disruption, or perhaps all updates, or perhaps even creating additional updates such as on a weekly basis. (How to create additional updates between historically recorded updates may be the topic of another article). These should individually be saved as ####diag.out files, where #### represents the update number.

A dBase file will now also be required to simply list the updates involved, such as in shown in figure 3 for Windows RW02 through RW18 (continuing in this analysis to RW34).

Several additional dBase files will need to be created for absorption of the P3 Diagnostic data and conversion to run this Out-of-Sequence Disruption Diagnostic. (Again see the Online Content button at www.aacei.org). The output from this program is shown in figure 4 which indicates two examples of potential disruption. The first indicates that a Column Pier 6S was started before the completion of Column Pier 8S as initially planned. Why is not yet noted. Was this an instance where additional contractor crews jumped ahead, or was completion of 8S somehow disrupted? If the former, is there a cost associated with bringing in a second and possibly lesser trained crew? If the latter, what costs will be incurred to bring the crew back to complete 6S one the disrupting causative event is resolved? This issue has just arisen as it is noted as a new disruption during update or window #2.

The second example indicates that electrical work has started on an elevator but will need to stop at some point as progress on installation of the elevator has stalled. This issue has been around since update 23 and we are now six months later in update 29. Thus, not only will cost be incurred to the elevator installer, but also to the electrical subcontractor.

The entire process may be summarized as depicted in figure 5. The text printout of the Oracle Primavera P3 schedule diagnostic report is imported to a dBase file, additional information is exported directly from P3 to a dBase file, these are combined to form a powerful database from which patterns of disruption may be seen and to which specific costs can be assigned. Rather than complain of being attacked by a swarm of bees. the individual injuries and costs of the 1000 bee stings may be addressed.

## Conclusion

The as-planned logic represents the project manager's "plan of execution" and, presumably, the most expedient and cost effective means to perform the scope of work of the project. When the project manager is hindered from performing work according to this plan, there additional costs can be expected, even if the disruptions incurred do not impact the current critical path of the project. Review of selected updates to determine which activities were performed out-of-sequence and why can be used to prepare or defend a claim of disruption. ◆

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