CDR.02

Daily Delay Measure: A New Technique to Precisely Identify Delay

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A new schedule analysis technique, the daily delay measure (DDM), is a significant new tool to assist in forensic schedule delay analysis. It allows the expert, at the earlier stages of the forensic analysis, to identify probable critical and near-critical paths. This early identification allows the expert to better focus analysis efforts and to more productively exclude activities or activity groups from consideration during the detailed analysis.

This tool permits the expert to track the schedule status of every activity on any regular, periodic basis and to identify which activities and/or groups of activities change their schedule status as the project progresses. This methodology was developed primarily in the context of forensic as-planned vs. as-built delay studies, but is also useful in other forensic delay methodologies including "collapsed as-built" and "windows." DDM is a continuous arithmetic measure of an activity's delay relative to the plan, and can identify when critical shifts occur from one activity to another.

WHAT IS REQUIRED FOR THE ANALYSIS?

DDM is predicated on comparing the original baseline schedule as-planned dates (generally the late dates) with the actual start and finish dates of those same activities. The authors assume an accurate baseline schedule is available that comports with the contract requirements and represents the planned sequence and duration of activities prior to any actual progress. It is recognized in many cases that the schedule expert may have to modify an early schedule by removing subsequently inserted activities or "destatusing" the schedule by removing progress.

Corresponding actual start and finish dates are also required. As with all forensic schedule analysis, the accuracy of these bits of data is essential to the analysis. The authors presume that if monthly updates, for example, have been maintained, they represent reasonably accurate actual start and finish dates. However, since only actual start and finish dates are compared to planned dates, intermediate schedule updates such as monthly CPM updates, are not necessary.

The number of activities included in a DDM study has an impact on its likely usefulness. As with any schedule analysis tool, the fewer the number of activities included in the study, the less useful, less reliable, and less detailed the study. Most of the discussion that follows assumes that the expert schedule analyst has certain schedule criteria available for use, including:

- Activity ID
- Activity description
- Planned start dates
- Planned finish dates
- Actual start dates
- Actual finish dates

The authors have found that the early start and finish dates are not required for a DDM analysis. Since the purpose of the analysis is to identify the as-built critical path and the near critical paths, the analysis compares the late start and finish dates with the actual. Therefore, any float that may be associated with the activity is ignored. For activities that have float (and were therefore probably not on the as-planned critical path) they will generally not appear as delayed at the early stages of performance since they will generally, under the DDM methodology, appear as "ahead" of schedule. As the analysis progresses through the project, these activities with initial float, if they remain delayed, can overtake activities that were on the as-built critical path.

This methodology also ignores some of the inconsistencies brought to schedule analysis by the use of multiple calendars. While multiple calendars are often essential to the proper planning of a project, they can often imply incorrect critical paths.

Further, it is assumed that the actual dates are accurate, but it is recognized that they might not be completely accurate. If the DDM analysis is performed prior to establishing the accuracy of the as-built dates, some of the initial results from the DDM analysis may need to be revised after the accurate dates are established. However, the authors believe the advantages of the early identification of activities for the critical and near critical path outweigh the possible inaccuracies associated with inaccurate as-built dates. In the situation where the as-built dates are unknown at the start of the analysis due to the failure to maintain the necessary records, the DDM analysis will have to await the identification of those dates.

The planned duration is also important since the analysis can allow for planned durations in its calculation of delay (see option 1 below). For example, if an activity with a planned duration of 10 calendar days (CD) starts 5 CD late, it is 5 CD late to the start, and retains that delayed start for the entire planned duration. As is evident, the DDM analysis is predicated entirely on actual calendar days—workdays have no role in this analysis, and all durations expressed in workdays should be converted to calendar days.

PERFORMING THE ANALYSIS

The authors have preformed DDM calculations using spreadsheet programs such as MS Excel, and database programs such as MS Access. To illustrate the complicated calculations involved, Figure 1 is applicable to either a spreadsheet or database application. Since the calculations are made for every day on each activity, there are a very substantial number of calculations, and each calculation contains a significant number of steps.

The initial product is a large numeric spreadsheet that shows, on a daily basis, how many days a particular activity is ahead or behind schedule. Therefore a typical cell in the spreadsheet contains a formula similar to Figure 1.

The authors have found that when applied to an Excel spreadsheet, this generic formula exceeds the cell limitations for formulas. As a result, a series of "intermediate formulas has been developed that break the activities into one of six cases. Figure 2 depicts these six cases.

GRAPHIC REPRESENTATIONS OF THE DDM

There are two methods the authors have utilized in presenting/reviewing the results of the DDM. The first is a familiar bar chart where each activity has its own row, with each cell indicating the number of days early or late the activity is on any given day. This allows the expert to readily identify the relative value of each activity on any given day, identifying which activities are delayed, including the activity that is most delayed. As with all preliminary analyses, it must be stressed that this initial selection is probably not the as-built critical path.

Figure 3 provides an example of a portion of such a graphic spreadsheet. This example is based on a small medical building. The authors plotted all activities that contained significant delays for each month. These activities were then organized by actual start date and arrayed so each activity was a series of numbers depicting number of days late. This allows a simple review to ascertain which of the various activities are most delayed and the degree to which the most delayed activities change as the project progressed. The authors added a heavy red line to depict, in a preliminary manner, the probable as-built critical path. These charts are, by necessity, hundreds or thousands of rows on a side, so only a small sample is shown here.

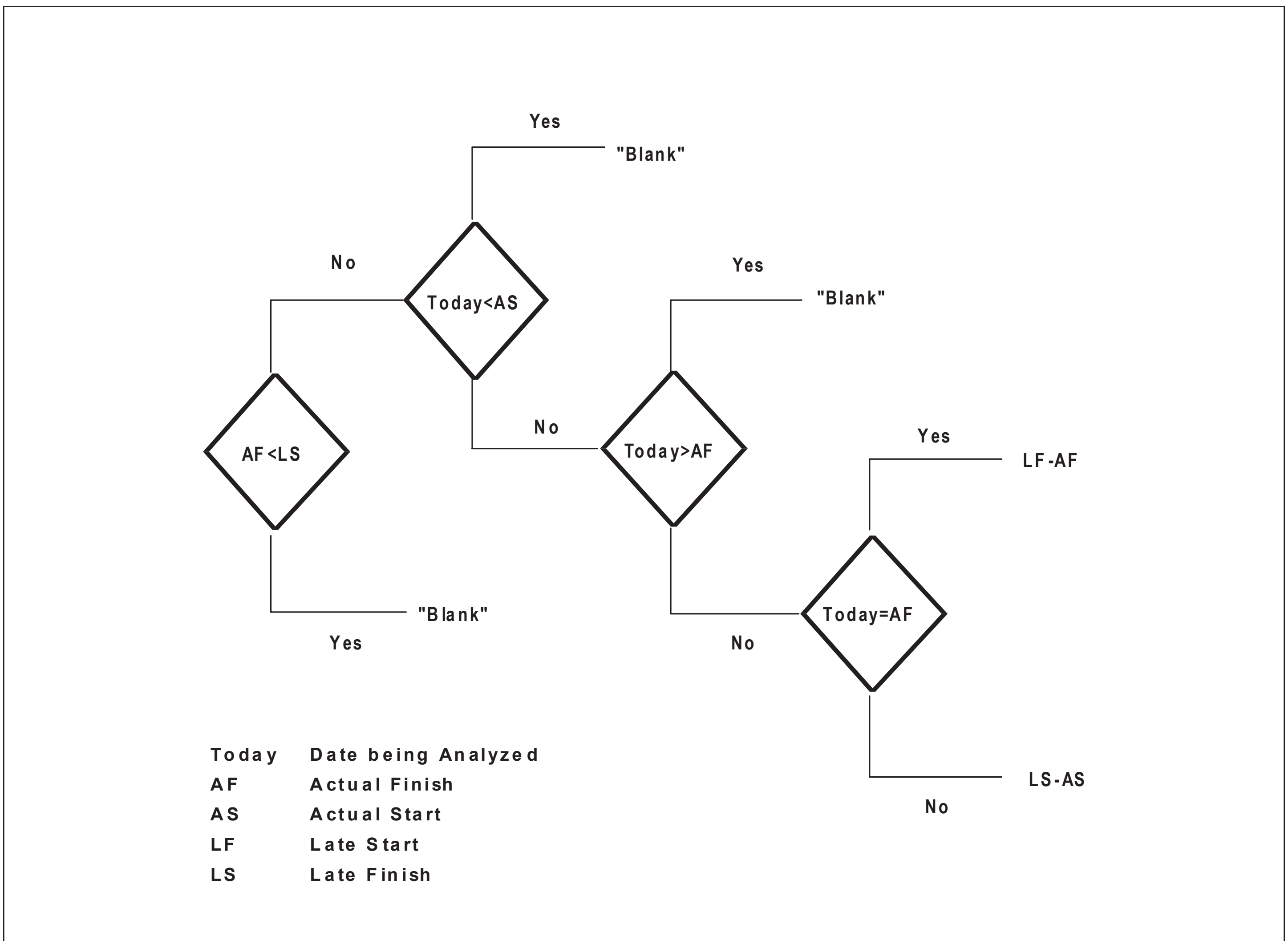

Figure 1

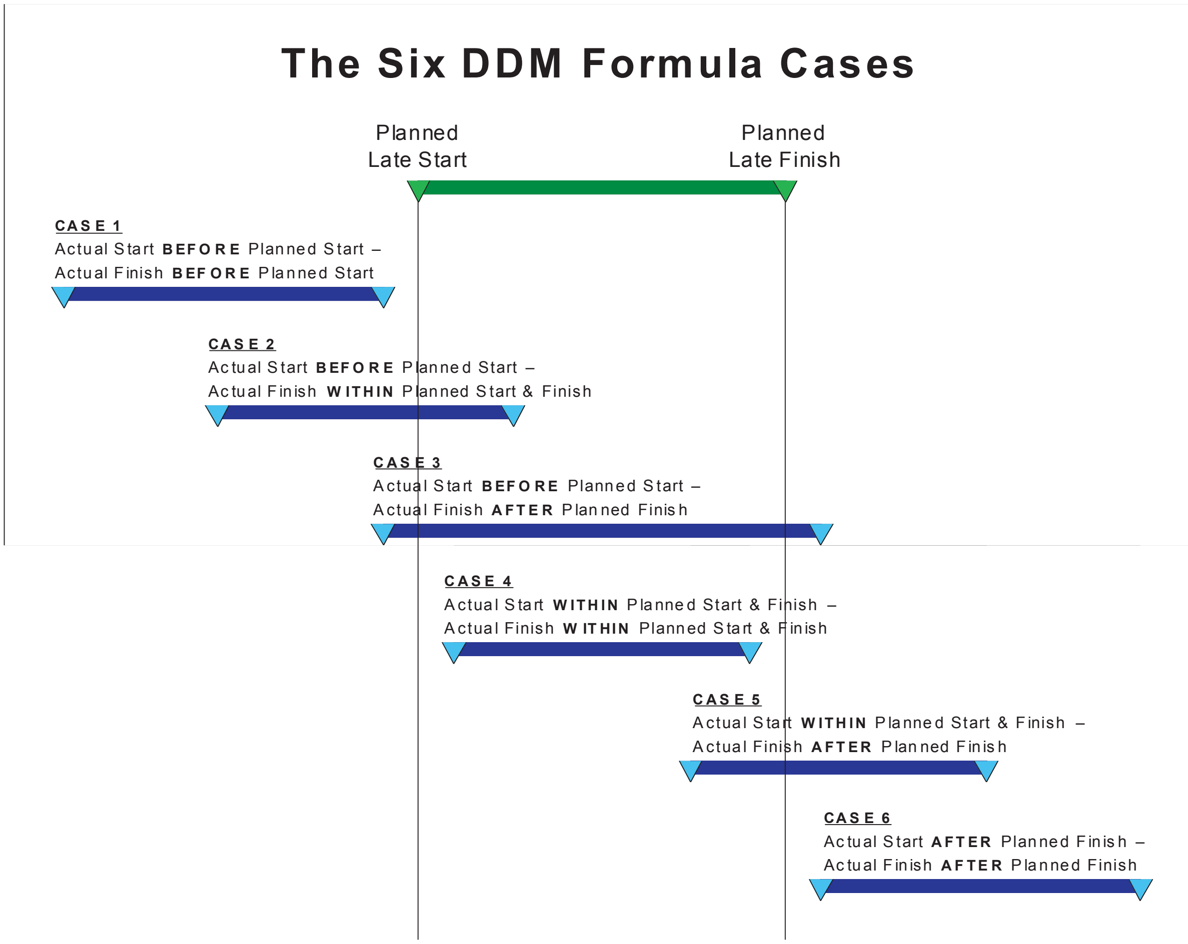

Figure 2

Medical Office Building - Daily Delay Measure

Activity #	TITLE	es	ef	ls	lf	Duration (LF-LS)	Float (LF-EF)	as	af	Late Start (AS-LS)	Actual Dur (AF-AS)	Actual Late (AF-LF)	LS or AS		AS plus planned duration
00001	Notice to Proceed	1-Sep-99	1-Sep-99	09-Sep-99	09-Sep-99	0	8	1-Sep-99	1-Sep-99	-8	0	-8	1-Sep-99	Type 2	1-Sep-99
01081	Mobilize	09-Sep-99	13-Sep-99	15-Oct-99	19-Oct-99	4	36	1-Sep-99	1-Sep-99	-44	0	-48	1-Sep-99	Type 1	5-Sep-99
02011	Site Demolition / Clearing	10-Sep-99	23-Sep-99	18-Oct-99	29-Oct-99	11	36	9-Sep-99	4-Oct-99	-39	25	-25	9-Sep-99	Type 2	20-Sep-99
02051	Sanitary Sewer	25-Oct-99	29-Oct-99	17-Feb-00	24-Feb-00	7	118	27-Sep-99	1-Nov-99	-143	35	-115	27-Sep-99	Type 2	4-Oct-99
02021	Rough Grade - Site	27-Sep-99	08-Oct-99	20-Jan-00	02-Feb-00	13	117	5-Oct-99	17-Nov-99	-107	43	-77	5-Oct-99	Type 2	18-Oct-99
02141	Rough Grade Building Pad	22-Sep-99	24-Sep-99	28-Oct-99	01-Nov-99	4	38	5-Oct-99	12-Nov-99	-23	38	11	5-Oct-99	Type 3	9-Oct-99
03010	Concrete Foundations	19-Oct-99	25-Oct-99	02-Nov-99	08-Nov-99	6	14	12-Oct-99	25-Oct-99	-21	13	-14	12-Oct-99	Type 2	18-Oct-99
Activity #	TITLE	es	ef	ls	lf	Duration (LF-LS)	Float (LF-EF)	as	af	Late Start (AS-LS)	Actual Dur (AF-AS)	Actual Late (AF-LF)	LS or AS		AS plus planned duration

SEPTEMBER

Activity #	12-Sep-99	13-Sep-99	14-Sep-99	15-Sep-99	16-Sep-99	17-Sep-99	18-Sep-99	19-Sep-99	20-Sep-99	21-Sep-99	22-Sep-99	23-Sep-99	24-Sep-99	25-Sep-99	26-Sep-99	27-Sep-99	28-Sep-99	29-Sep-99	30-Sep-99
00001																			
01081																			
02011	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39	-39
02051																-143	-143	-143	-143
02021																			
02141																			
03010																			

OCTOBER

Activity #	1-Oct-99	2-Oct-99	3-Oct-99	4-Oct-99	5-Oct-99	6-Oct-99	7-Oct-99	8-Oct-99	9-Oct-99	10-Oct-99	11-Oct-99
00001											
01081											
02011	-39	-39	-39	-25							
02051	-143	-143	-143	-143	-143	-143	-143	-143	-143	-143	-143
02021					-107	-107	-107	-107	-107	-107	-107
02141					-23	-23	-23	-23	-23	-22	-21
03010											

25 CD Early

SEPTEMBER | OCTOBER

Figure 3

Graphics similar to this are useful in identifying areas to be investigated, and in explaining to clients the relationship of schedules pertaining to identifying the as-built critical path.

A second type of graphic representation is also useful, and may in certain circumstances be more readily understandable. In this graphic, the delay is plotted in a chart with other identified activities. While not all activities can be graphically depicted in this manner (there would be too many lines), major activities and candidates for the as-built critical path can be shown, and the observer can get a readily understandable view of the evolution of the delay.

In Figure 4, the entirety of the summary level DDM analysis is depicted for the example medical building utilized previously. The three lines shown summarize the total overall delay, and the distribution between owner responsibility and contractor responsibility.

Figure 4 depicts the standard calculation for a DDM, option 1—standard model. The next section describes and illustrates the differences between the standard model and two other options identified by the authors.

OPTION 1—STANDARD MODEL

The standard model depicts the activity retaining its schedule status on the first day of performance for the entire duration of planned performance. For example, if the activity started 5 CD late, it would have a DDM of 5 (5 days late) for the entirety of the planned duration. If the work, once started, were performed in the planned duration, then on the final day of performance it would be 5 CD late. Alternatively, if the activity took longer to perform than the original planned duration, then at the end of the planned duration, it would start to accumulate delay on a day-for-day basis (Figure 5).

As stated before, this methodology does not replace standard processes for identifying the as-built critical path. The authors realize that no mere computer program can calculate the as-built critical path—it requires careful analysis of the events of the project and the real and logical relationships between the activities. Indeed, the DDM ignores the logical relationship between activities—hence the need for expert evaluation.

The authors have identified and used a modification that can further streamline this methodology and assist the forensic schedule expert. In many projects the number of days a particular activity is delayed need not be known on a daily basis. Although the

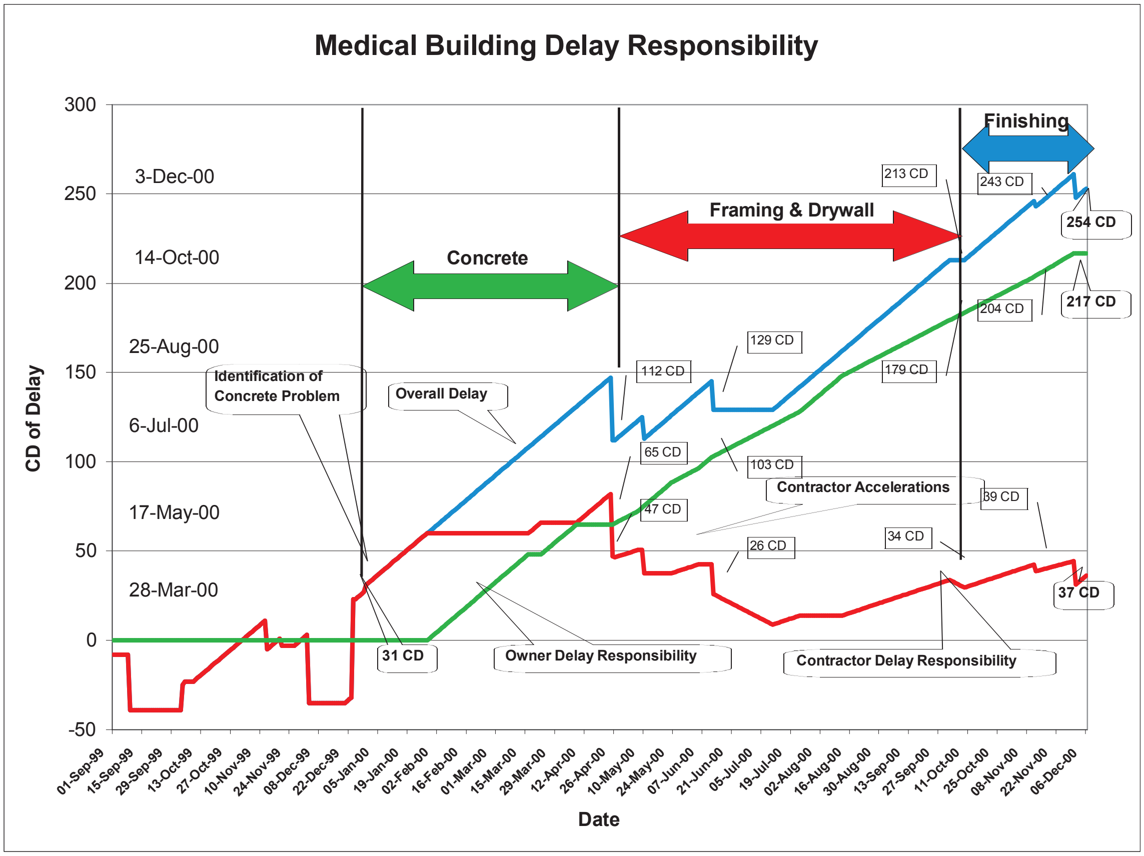

Figure 4

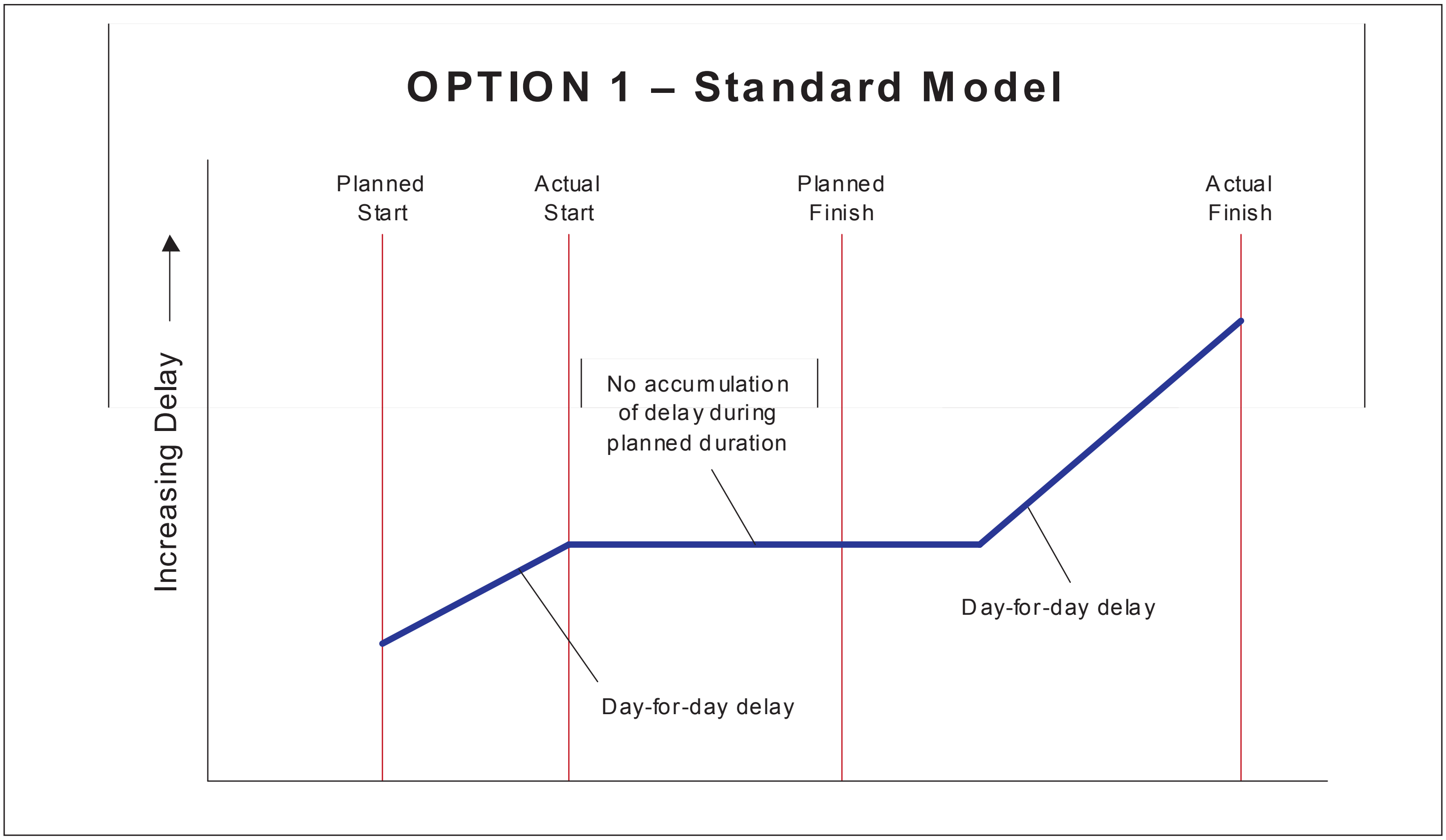

Figure 5

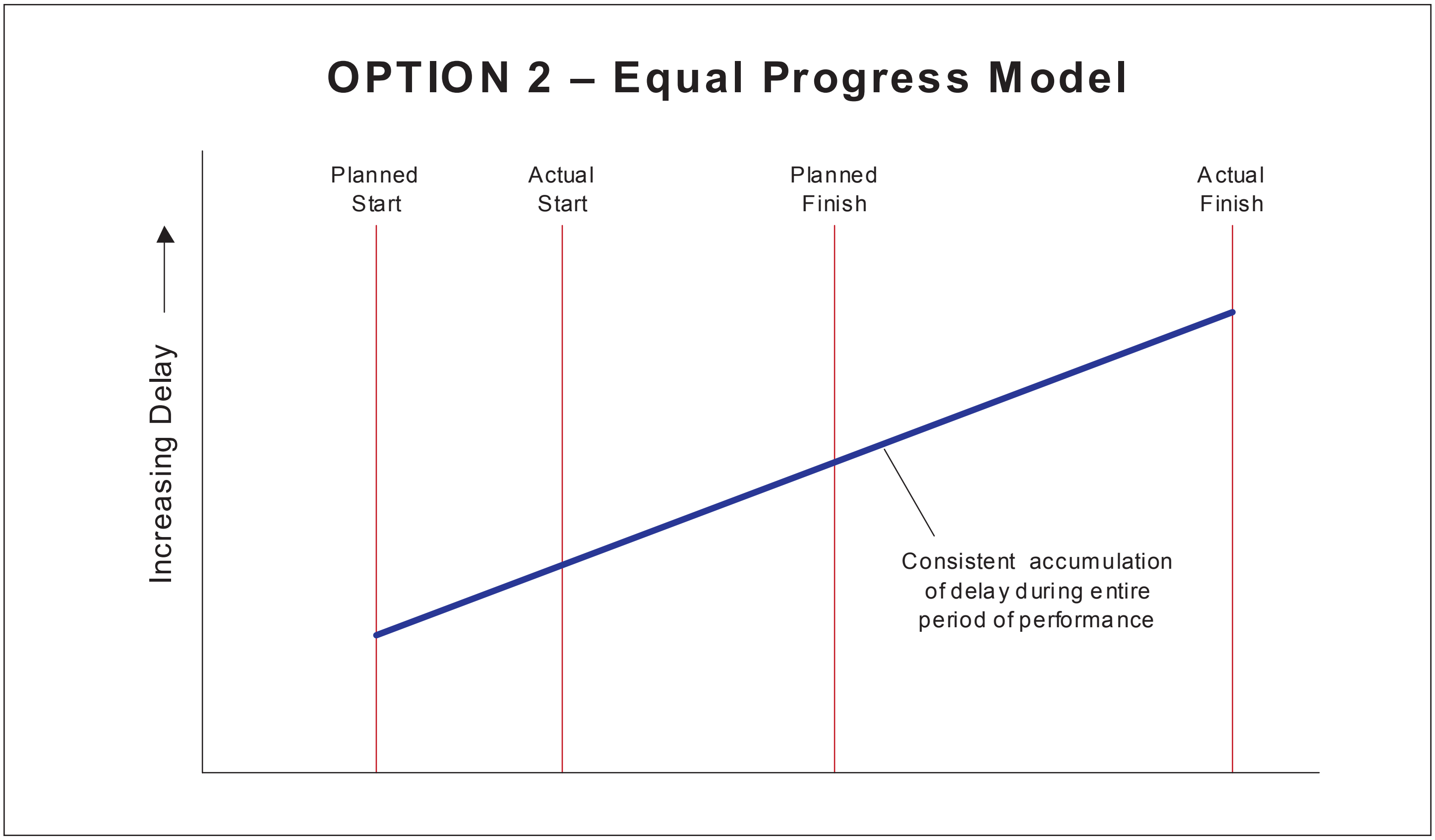

Figure 6

computer can calculate it every day, for projects with durations measured in years rather than months, it is probably not essential to know the delay each day—although when the critical path shifts from one activity to another that may be essential. As a result, the authors have performed the calculations on a weekly and in some cases a monthly basis.

OPTION 2—EQUAL PROGRESS MODEL

In option 2, the treatment of planned duration is changed in the calculation methodology. In the basic DDM calculation (option 1—standard model), the activity delay does not increase during the period of planned duration, regardless of how late it started or how long it took to complete.

However, since the DDM methodology is retrospective, and the actual finish date is known, the analysis can be performed assuming that actual performance proceeds steadily (in a straight line) over the entire period from actual start to actual finish. The authors recognize that such an assumption is generally untrue, but it does provide a representation of the progress. For example, if an activity with a planned duration of 10 CD starts 5 CD late and actually takes 20 CD to perform once started, it finishes 15 CD late (5 CD late start plus 10 CD of performance in excess of the planned 5CD duration).

But how delayed is the activity after 10 CD of performance (15 CD after planned start)? The regular method indicates the activity is only 5 CD late on this date, while the retrospective alternative methodology indicates the activity is 7.5 CD late (Figure 6).

OPTION 3—ACTUAL PROGRESS MODEL

DDM option 3 is significantly more refined than the first two. However, this variation is generally not available to the forensic schedule expert, as few contractors or owners maintain records sufficient to permit it. In this option, the rate of increased delay is not a single sequence or series of straight lines, as in options 1 and 2 above. Instead, actual progress each day (or week if that is the measuring increment) is used. The result may be similar to that described in option 2 above, but it is more likely that production is not a straight line and the number of days delayed follows its own curve. The following formula illustrates how this calculation is made:

$$\left[\frac{\text{Percent Remaining}}{\text{Percent Complete/Days of Performance}}\right] - \left[\left[\begin{matrix}\text{Actual Start Date}\\ +\\ \text{Planned Duration}\end{matrix}\right] - \text{Analysis Date}\right]$$

(equation 1)

Figure 7 charts the values derived from the above formula in the guise of a series of curves. As would be expected, many activities follow an S-curve typical of a slow start and slow finish.

Figure 8 depicts a delay graph based on the actual progress model. On this particular project, a major far-east airport, the contractor kept detailed logs on numbers of identical (or near identical) elements installed on a daily and weekly basis. These elements each were the culmination of a long and complicated series of installation activities. Each of the element types was largely independent of each other for purposes of installation, although there were possibilities of interference and access to equipment. The graph shows the increased delay associated with each of the disparate element installations. The as-built critical path followed the activity group that was most delayed at any point in time. Stated another way, the as-built critical path was always the activity represented by the line highest on the chart at any point in time.

COMPARISON OF DDM OPTIONS

While the authors would prefer in almost all cases to depict progress of each activity in accordance with option 3, the availability of data severely impacts its use. In fact, the authors have only been able to use the method on one commercial building project and several industrial projects. Such records are simply not normally maintained on typical building construction projects. As between option 1 and 2, there are advantages to each. option 1 depicts how the progress might be viewed contemporaneously—if the activity's work starts a few days late, the activity retains that degree of lateness until its planned performance period has passed. Option 2 is truly a classic, forensic, after-the-fact view.

By way of comparison of the three methods, the authors have constructed a hypothetical example as it pertains to one activity, and how these options treat the resulting delay. The activity commences a few days earlier than planned and advances at a nonconsistent rate, as depicted by the percent complete. Table 1 shows the assumptions, and the graphic depicts the product derived from each of the various options (Figure 9).

DDM AND COMPUTERIZED SCHEDULE PROGRAMS

DDM is similar to certain applications contained in scheduling software such as Primavera P3 Project Planner. The similarity is rooted in the application that identifies the variance between the dates of one schedule activity as compared to corresponding dates for the same activity in another "target" schedule. The resulting data yields the arithmetic difference between the dates (early start, early finish, late start, late finish) for common activities. DDM performs much the same type of function, but that is where the similarity ends. The scheduling software application measures the difference between two established sets of activity data; a relatively static review. DDM however, not only measures the change in value, but goes on to chart the synthesis of the variance as it occurs over the course of the time frame being reviewed; a dynamic review.

In simple terms, DDM performs a target variance calculation for each activity for each day, spanning the entire range of time encompassed by the planned execution and the actual execution.

Because scheduling software only measures the difference between prescribed dates, it is restricted from identifying the change dynamic in between one schedule and another. For example, most scheduling software can determine the difference the early start date of one activity as contained on one schedule—the

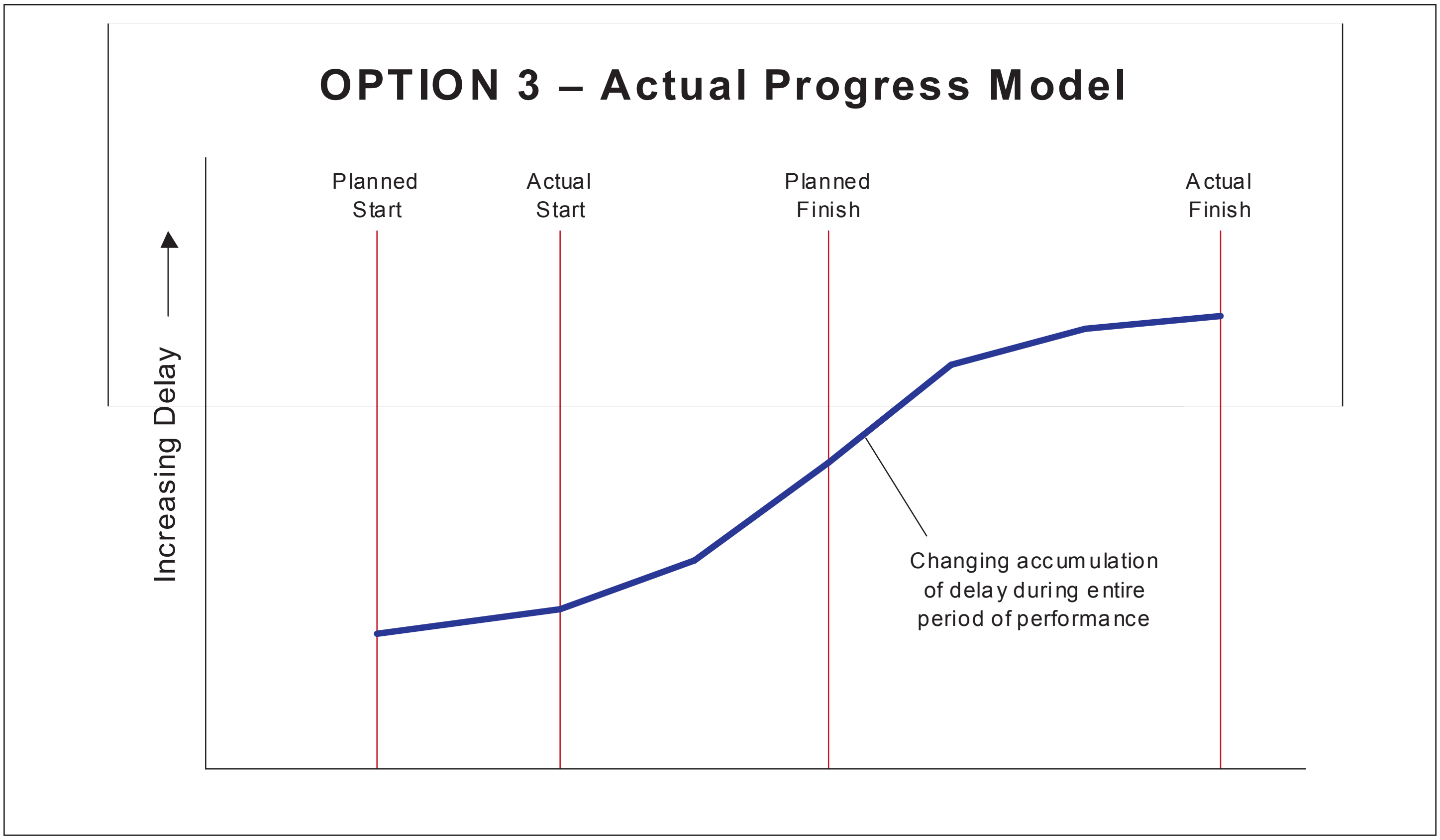

Figure 7

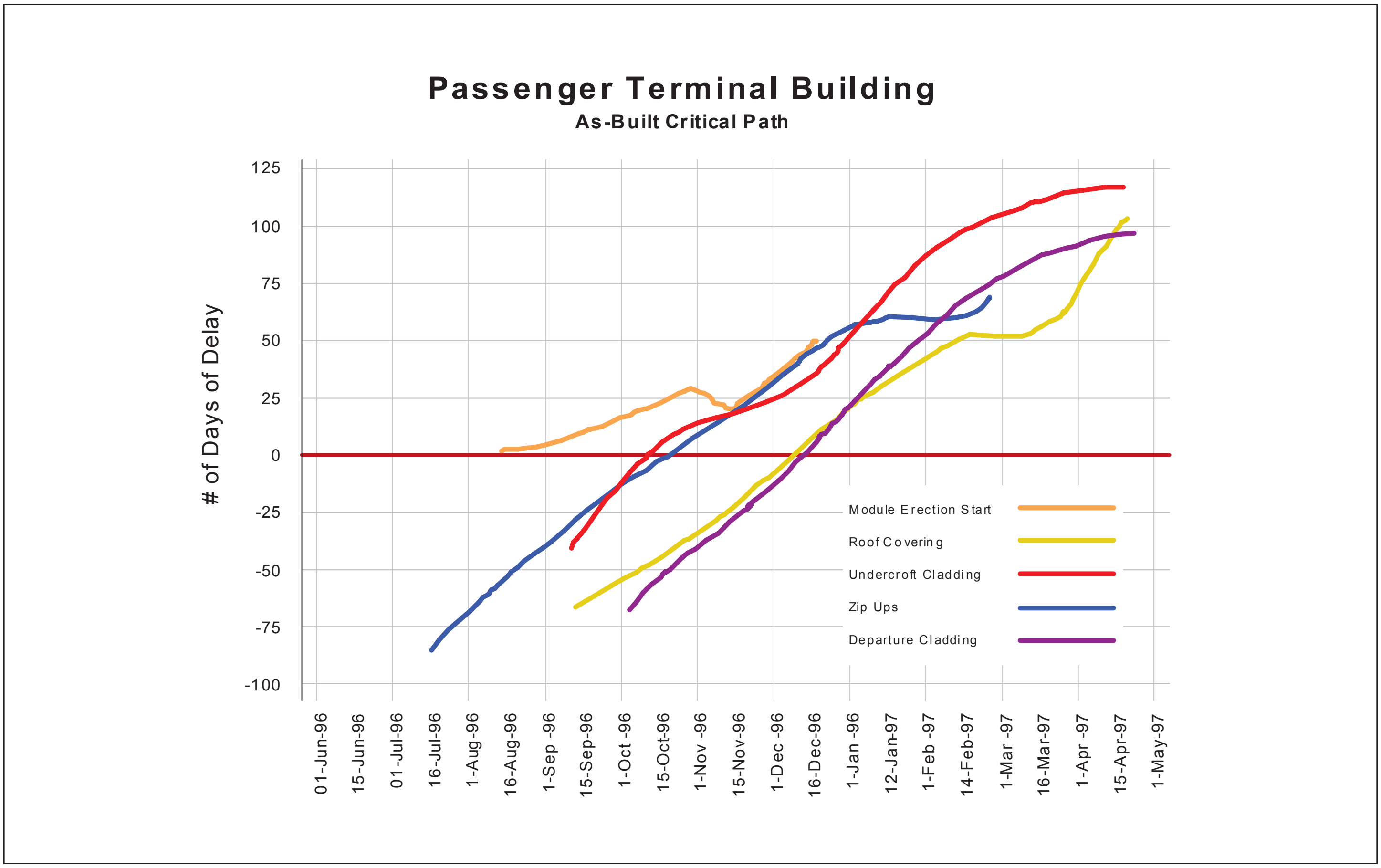

Figure 8

Table 1

Calendar Day	1	2	3	4	5	6	7	8	9	10	11	12
Planned Cummulative Percent Compete	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%
Actual	0%	0%	5%	10%	15%	20%	22%	24%	26%	29%	32%	35%
Option #1	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Option #2	0.00	0.00	0.43	0.87	1.30	1.74	2.17	2.61	3.04	3.48	3.91	4.35
Option #3	0.0	0.0	7.0	7.0	7.0	7.0	9.7	12.0	13.9	14.6	15.1	15.6

Calendar Day	13	14	15	16	17	18	19	20	21	22	23	24	25
Planned Cummulative Percent Compete	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Actual	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Option #1	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Option #2	4.78	5.22	5.65	6.09	6.52	6.96	7.39	7.83	8.26	8.70	9.13	9.57	10.00
Option #3	14.5	13.7	13.0	12.5	12.0	11.6	11.3	11.0	10.8	10.5	10.3	10.2	10.0

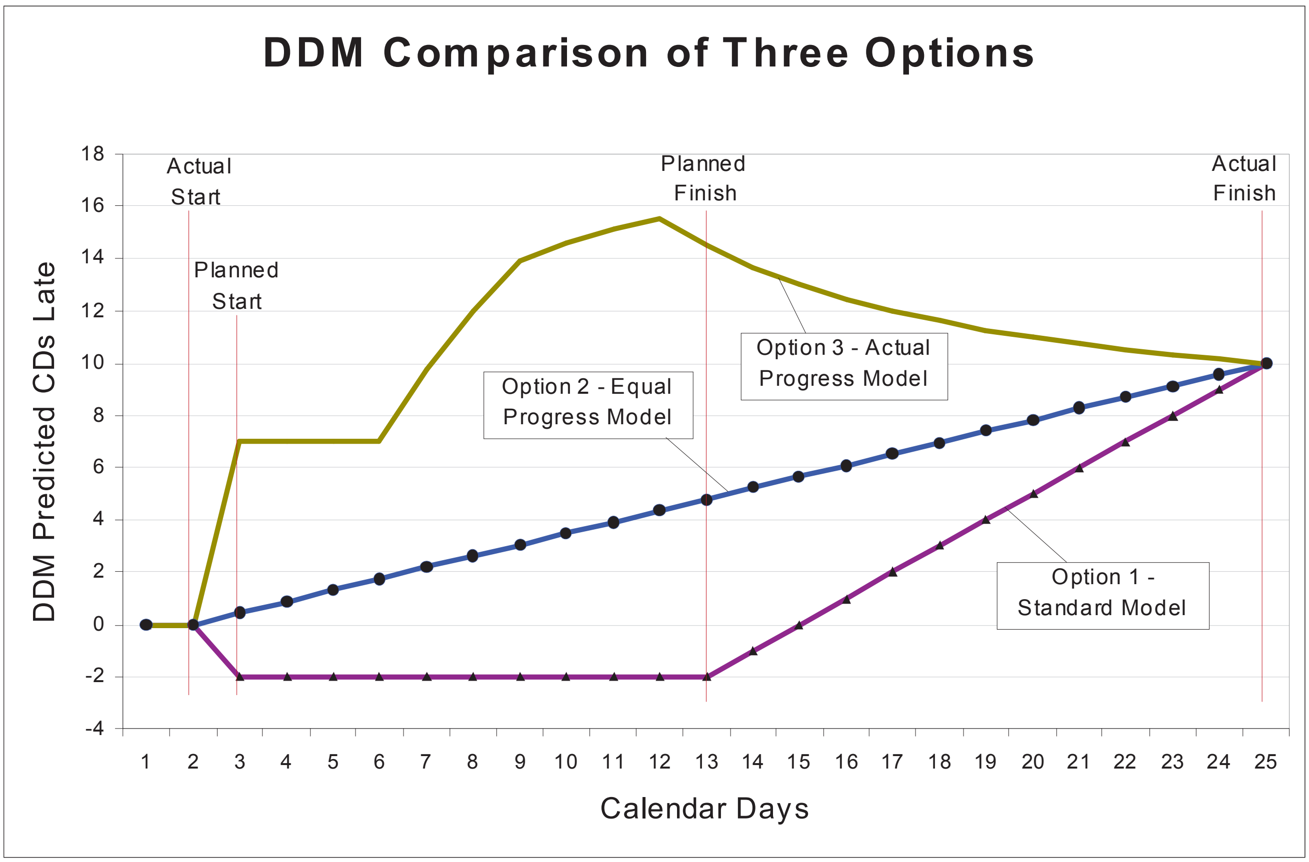

Figure 9

"baseline"—as compared to the early start date of that same activity on another schedule—the "target." It does not, however, identify or illustrate how the variance evolves over the timespan between the two schedules; which is exactly what DDM is capable of providing.

DDM AND VARIOUS SCHEDULE METHODOLOGIES

The authors and their associates have used this technique on dozens of schedule delay analyses undertaken in the past few years. While most of these schedule delay analyses have been performed using the most judicially acceptable methodology—the as-planned vs. as-built comparison—some of these DDM analyses have been used in impacted as-planned and collapsed as-built delay analysis methodologies. In each case, the early identification of schedule areas, paths, and/or sequences that were significantly delayed assisted in identifying the activity path(s) most impacted by events or conditions that occurred on the project.

The DDM provides schedule experts a fast and mathematical method for identifying areas of work that were delayed. The methodology can be applied in several different models, depending on the experts' needs and the availability of data. The authors have not, as of this writing, presented the methodology in a court, although several cases are currently pending that utilized DDM as one of their analysis tools. It is therefore impossible to know how courts may view this methodology. However, the authors believe that the DDM, when used in conjunction with a well-recognized schedule delay technique such as the as-planned vs. as-built comparison methodology, will prove acceptable.

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