CHAPTER FIVE

Measuring Delays—The Basics

The method used to measure or quantify delays on a construction project will generally be a function of and dependent upon the type and quality of documentation that is available for analysis. The majority of this book discusses delay analysis in the context of CPM schedules that have been determined to reliably model the plan and progress of construction. However, regardless of the method chosen, there are five essential principles that should be used to guide every analysis of delays.

DELAY ANALYSIS PRINCIPLES

Delay analysis principle no. 1—only delays to the project critical path can delay the project

This principle has already been introduced in earlier chapters, because it is the basic principle upon which the analysis of delays is based. The proper application of this principle relies on the correct identification of the critical path. This is something that is not only easy to do correctly but also easy to do incorrectly.

As discussed in Chapter 2, Float and the Critical Path, and also below, the project critical path is the longest path of work through the schedule network and, as such, forecasts when the project will finish.

Delay analysis principle no. 2—not every delay to the critical path will delay the project

Although only delays to the critical path can delay the project, not every delay to the critical path will delay the project. As discussed in Chapter 2, Float and the Critical Path, the critical path can include critical activities that have positive total float values. If this circumstance exists, then these critical path activities can be delayed without delaying the project. The number of days of delay that can be absorbed will depend on the number

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of days of total float. This situation is more common on construction projects that are subject to seasonal or environmental work restrictions.

Delay analysis principle no. 3—the critical path is the longest path

As demonstrated in Chapter 2, Float and the Critical Path, the critical path is the longest path. Why is this principle essential? As explained in Chapter 2, Float and the Critical Path, the use of multiple calendars and activity constraints will affect the total float values of activities in the schedule. As such, total float values alone cannot be used to identify the project's critical path in every schedule.

CPM scheduling software packages acknowledge this complexity and have embedded a feature called the longest path filter that allows users to identify the longest path of work in the schedule network. In fact, as described in Chapter 2, Float and the Critical Path, Oracle's Primavera Project Management (P6) scheduling software manual states that if a CPM schedule uses multiple calendars, then "using total float values to identify critical activities may prove misleading, since some activities have large float values due to their calendar assignments but are still critical to the completion of the project." In these circumstances, the longest path filter becomes the most reliable tool for identifying the critical path.

Delay analysis principle no. 4—the critical path can and does shift

The critical path is dynamic in nature and may change, or shift, during the project. Shifts to the critical path depend on how the project is planned; how the project work progresses or does not progress; and changes made to the schedule logic. Because critical path shifts occur while the project is progressing and when changes are made to the schedule, delay analysts should identify and account for shifts in the critical path when identifying and measuring project delay.

Delay analysis principle no. 5—activity delay and project delay are not the same

It is important to understand the difference between activity delay and project delay. While the delay to an activity may be important, in that there may be consequences when an activity starts or finishes later than it was planned to start or finish, each day of delay to an activity will either consume float or delay the project, but not both. Understanding the activity's position in the network and its total float value relative to that of the critical path is essential to determining when the delay to an activity has delayed the project. This, of course, relates back to Delay Analysis Principle No. 1.

Evaluating delays prospectively and retrospectively, what is the difference?

The first step in answering this question involves defining these two terms—prospective and retrospective.

The Merriam-Webster dictionary defines the term prospective as "relating to or effective in the future." The term retrospective is defined as "of or relating to the past or something that happened in the past."

These are the definitions, but what is the distinction between these two terms as they relate to the analysis of delays? As their definitions suggest, a prospective analysis of delays estimates or forecasts the delay caused by an event or a change in the future, before the affected or changed work is performed. In contrast, a retrospective analysis of delay identifies delays that have occurred in the past, after the affected or changed work is completed. A good analogy of these methods is the pricing of a change. A prospective analysis is like the forward pricing of a change in which an owner and a contractor agree to an estimated value of the work, prior to the work being performed; a retrospective analysis is like the T&M or "force account" pricing methods, which determine the actual cost of the work after it is performed.

With regard to prospective delay analysis, there is nearly universal industry agreement that the Prospective Time Impact Analysis method, known simply as Time Impact Analysis, or TIA, is the best method to forecast the delay resulting from an event or change before the affected or changed work is performed. The TIA method consists of creating a fragmentary network, or "fragnet," which consists of creating a network of activities that represent the event or change, and inserting that network into the current version of the project's schedule update. The schedule update file containing the fragnet for the change order work is recalculated or rescheduled to determine whether the added activities forecast a delay to the project.

Unfortunately, with regard to retrospective delay analysis methods, there is no consensus or agreement on the best method. In the remainder of this chapter, we explore some of the more commonly used approaches.

THE IMPORTANCE OF PERSPECTIVE

Reality is a question of perspective; the further you get from the past, the more concrete and plausible it seems.—Salman Rushdie, Midnight's Children

The identification of a critical delay is often a question of perspective. Every analyst has a way of illustrating this point, but the classic example is the "ribbon-cutting" story. Consider a project where, in addition to all its other responsibilities, the contractor must also provide the scissors for the mayor's ribbon cutting at the conclusion of the project. The architect rejected the contractor's original scissor submittal (the Contract specified something larger and grander). The project manager for the contractor shoved the rejected submittal to the bottom of the "to-do" pile, where it languished and was eventually lost. The project ultimately finished late due to an error in the design of the structural steel. The error necessitated refabrication of the steel, which was on the project's critical path. This delayed the start of the structural steel erection work that, in turn, delayed the project.

At the ribbon-cutting ceremony, it quickly became apparent that the scissors had not been purchased. The project manager, at the last minute, ran to the local office supply store and bought the biggest, brightest pair of scissors in stock and returned to the project site just as the mayor was about to cut the ribbon. As a result, the proceedings were held up only a few seconds as the project manager ran up to the entrance of the new water treatment plant.

After the ribbon-cutting ceremony, the project manager met with the architect to close out the project. The contractor sought a time extension due to the steel design error. The architect rejected the contractor's request, stating that even without the steel design error, the formal opening of the project would have been delayed by the lack of scissors to cut the ribbon.

The ribbon-cutting story points out the importance of perspective. Viewed solely from the end of the project, which we may call an after-the-fact or as-built perspective, the lack of a pair of scissors, and the flawed procurement process that caused them to be delivered just in time, could be considered critical to opening the project. Given these facts, most of us quickly see the error in the architect's logic. But what if the scissors are changed to aluminum tank covers? In response to the steel design error, assume that the project manager called the fabricator of the aluminum tank covers to let them know that the project would be a little late and that the delivery of the tank covers should be postponed. If the tanks were not ready when the covers were delivered, they would have to sit before they could be installed and might be damaged. As the project manager recommended, the tank covers were delivered later than originally scheduled, but they finally arrived and were installed as the delayed tanks were completed.

In this alternate story, the contractor and the architect again meet after the ribbon cutting to close out the project. Again, the contractor asks for a time extension, and, again, the architect refuses the request. This time, however, the architect denies the time extension because the "aluminum tank covers were late." We know all the facts, in that the aluminum tank covers were intentionally delivered when they could be immediately installed. So we, again, see the error in the architect's logic. But what if the facts were not known? What if there was no written record of the project manager's conversation with the tank cover fabricator? Absent verifiable facts, is the architect correct? Is the as-built perspective a relevant and valid way to view the project events and evaluate the critical project delays?

Perhaps it is only the as-built perspective that is problematic. What about the view from the beginning of project, or the as-planned perspective? Consider the same project. As required by the contract, the contractor prepared a CPM schedule. The first schedule prepared on the project is called the baseline, or "as-planned" schedule. It should only depict the contractor's initial plan for completing the project and should not include "as-built" or actual performance information. The critical path of the project as depicted in the contractor's as-planned schedule proceeded through the erection of structural steel. During the close-out meeting, the architect requires the contractor to prepare an analysis that demonstrated that the steel design error delayed the project. The contractor concluded that the best way to evaluate or "measure" the delay associated with the steel design error would be to simply "insert" this delay into its as-planned schedule. In other words, the contractor chose to use a TIA, this time done retrospectively or after the fact, to analyze the delay. The contractor believed that by inserting a fragnet representing the steel design error into the as-planned schedule, the recalculated schedule would show both that the error caused a critical delay and the magnitude of the delay. If we did not know anything else, this approach might be acceptable.

But we do know something else. We know that a dispute developed between the contractor and its steel erector. In fact, the steel erector abandoned the project. The contractor was not able to get another erector on site until after the fabricated steel was delivered to the site. But the contractor's analysis does not consider this problem. The only fragnet inserted into the schedule is the fragnet for the steel error, and this causes a critical project delay. Is the contractor entitled to a time extension for the steel design bust regardless of what else might be going on at the project site when the delay occurred? Is the as-planned perspective a valid and reliable way to view the project events and evaluate the critical project delays?

In addition to evaluating the critical project delays using an as-built perspective or an as-planned perspective, another option would be to evaluate the critical project delays as they occur—in other words, evaluate delays to the project at the time the delay is experienced. This would avoid both the ribbon-cutting error and the flawed approach of inserting only the structural steel design fragnet into the as-planned schedule; rather it would force the analyst to consider everything that is happening on the project as delays occur. But what if the analyst is not brought in until long after the project has been completed? Is the view from the time when the delay actually occurred still relevant and valid, even though the analyst knows what ultimately happens?

The answer to the questions of perspective are at the heart of many of the disagreements among analysts regarding the best way to analyze delays on a construction project. Does the analyst evaluate the delay from the perspective of the beginning of the project, adding delays to the as-planned schedule, or from the end of the project, evaluating only those delays that appear to ultimately hold up the project's completion (the ribbon-cutting example)? Or should analysts try to put themselves in the shoes of the project team at the time the delay occurs? It would be disingenuous to suggest that analysts are united in their answers to these questions. There is, however, an emerging consensus supported not only by many analysts but by case law, as well.

Perspectives—forward looking and backward looking

Though rarer now, there was a time when delays were sometimes analyzed by "impacting" the as-planned schedule. The as-planned schedule is usually defined as the earliest complete and owner-approved project schedule. It represents the contractor's plan for completion of the project before work begins. If delays are analyzed using an "impacted as-planned" approach, the delay (or impact) is inserted into the as-planned schedule, and the schedule is then recalculated. The difference between the originally scheduled completion date and the completion date that results from impacting the as-planned schedule is the project delay attributable to the impact. This type of analysis takes the position that delays should be measured from the as-planned perspective that considers only the project team's original plan and the delay being analyzed. The problems with this analytical approach will be discussed in more detail in another chapter, but here's what a judge had to say about this approach in Haney *v.* United States [30 CCF ¶ 70, 1891], 676F. 2d 584 (Ct. Cl. 1982).

> *We have found that [the contractor's] analysis systematically excluded all delays and disruptions except those allegedly caused by the Government.... We conclude that [his] analysis was inherently biased, and could lead to but one predictable outcome.... To be credible, a contractor's CPM analysis ought to take into account, and give appropriate credit for all of the delays which were alleged to have occurred.*

Essentially, the judge's criticism was that the outcome of an impacted as-planned analysis, because it ignores everything other than the as-planned schedule and the delay the analyst is evaluating, was predetermined. It would overstate the delay, if any, associated with the inserted delay. Years of experience analyzing impacted as-planned analyses have confirmed this judgment. They very nearly always overstate the project delay, predicting project delays well beyond the actual project completion date. On this basis, an analysis of delays based solely on the as-planned perspective that employs an impacted as-planned analytical technique is flawed and should be avoided.

The logical opposite of an impacted as-planned analysis is the "collapsed as-built." Again, the problems with this analytical approach are discussed in another chapter, but a discussion concerning perspective is appropriate here. Stripped to its essentials, a collapsed as-built analysis is performed by first creating the "as-built schedule" for the project. This is essentially a schedule showing how a project was actually constructed. It is not a schedule that ever existed on the project, though it is theoretically composed of actual project events. The analyst creates the "as-built schedule" after the project is completed. The next step is to identify the delay or delays to be analyzed. Note that this approach is a little like the tail wagging the dog. The delay must first be identified before it can be analyzed. The analysis is performed by removing the delay from the as-built schedule and then rerunning the schedule to see what happens. If the collapsed schedule shows an earlier project completion date, then the conclusion would be that the delay that was removed was responsible for a project delay equivalent to the improvement in the project completion date. This analysis presumes that delays are best analyzed from the perspective of the end of the project.

Setting aside the questions concerning the mechanics of a collapsed as-built analysis, consider what it means. Essentially, the collapsed as-built approach is based on the assumption that all that matters is what happened, not what was planned. To understand the problems with this assumption, consider the following example. A contractor is tasked with excavating a 100-foot rock face and then lining the face with concrete. Excavation began, and the contractor immediately encountered a problem. It turns out that a fault zone ran through the area of construction. This fault zone was oriented in such a way that as the contractor removed rock, the rock face that was left tended to slip into the excavated area. This was not only dangerous, but it prevented the contractor from excavating the planned 100-foot rock face. The owner and the contractor met to discuss the problem, and they decided to pin the rock face with rock anchors as the face was excavated in 10-foot lifts. Also, the owner decided that the concrete lining had to be constructed before the next 10 ft of the rock face could be excavated.

At the conclusion of the project, the contractor asked for a time extension to cover the additional time it had expended excavating and lining the rock face in 10-foot lifts as opposed to all at once, as planned. The owner responded with a collapsed as-built analysis showing that the only delay was the time required to install the rock anchors, which had not been contemplated in the original design. The rock excavation and concrete liner were not "delays," since this work had always been required.

The fallacy of the owner's analysis was that in addition to the rock-anchor delay, the contractor was also delayed because it was required to build the project in 10-foot lifts rather than all at once, as planned. Because the owner's delay analysis considered only what happened (the as-built schedule), it could not quantify delays associated with deviations from the contractor's original plan. And this is the essential failure of any analysis based solely on what happened.

If the perspectives from the beginning of the project and the end of the project are flawed as shown in the preceding examples, the only perspective remaining is to analyze the project at the point where the delay actually occurred. An analysis based on this at-the-time perspective has a name. It is called a contemporaneous analysis. Before discussing how such an analysis might be performed, consider this judge's decision.

> *Mr. Maurer, appellant's expert, testified about the critical delays to the Project… The analysis about the critical delays was based on appellant's original schedule, the schedule updates, the daily reports, Project correspondence, and the contract documents. Mr. Maurer described his analysis as a step-by-step process, beginning with the original schedule and proceeding chronologically through the Project, updating the sequence at intervals to see what happens as the Project progressed [(tr. 262) ASBCA No. 34, 645, 90—3 BCA ¶ 12, 173 (1990)].*

The key point in this decision is that the analysis took into account all relevant project information as it became available to the project participants as the project progressed. In doing an analysis from this at-the-time perspective, the actual progress of all of the work is compared to the plan for the work as the project progresses, and considers all that the project participants knew at the time. In this manner, all delays that occur on the project are identified by the analysis instead of the delays being predetermined and tested by an analysis that either ignores other delays (beginning-of-the-project perspective) or ignores the plan (end-of-the-project perspective).

From this and other discussions in this book, it should become apparent that the only valid perspective for the analyst is the view of the project contemporaneous to the delay itself—not from the beginning of the project or the end of the project—but, at the time of a given delay. An analysis from this perspective is greatly aided by the project schedule.

USE THE CONTEMPORANEOUS SCHEDULE TO MEASURE DELAY

A contemporaneous schedule is the project schedule, which typically consists of the baseline schedule and schedule updates that were used to manage the construction project.

These contemporaneous project schedules are essentially snapshots of the project's status at specific moments in time. As snapshots in time, the schedule updates identify what work has been done and the order in which it was completed. These contemporaneous project schedules also capture changes made to the construction plan in reaction to ever-evolving project conditions.

The contemporaneous project schedules are the preferred tool to measure project delay because they were used by the project participants to manage the project and, therefore, provide the most accurate model of the plan to complete the project. They are, also, the only management tool that forecasts when the project will finish based on the then-known project conditions. These attributes provide the analyst with an at-the-time perspective of the team's plan to complete the project and enable the analyst to identify, measure, and assign responsibility for project delay using the same information available to the project participants at the time the delay occurred. By using the contemporaneous schedules, and by tracking delays as they occur throughout the project, there is no need to attempt to inject information that is known at a later date. Information is incorporated into the analysis based on contemporaneous information throughout the analysis.

DO NOT CREATE SCHEDULES AFTER THE FACT TO MEASURE DELAYS

In the absence of contemporaneous schedules, an analyst may feel it would be acceptable to create a schedule after the fact that he or she believes better portrays the contractor's intended construction plan. Although the analyst may rely on project documentation and, perhaps, firsthand knowledge of the type of construction being performed, creating a schedule for the sole purpose of measuring and identifying project delay after the project is complete undermines the perceived objectivity of the analysis. Even though the analyst may do his or her best to remain objective, because the actual events of the project are known, whether intentional or not, this after-the-fact knowledge influences the creation of the after-the-fact schedule and ignores, or at least significantly diminishes, the contemporaneous knowledge and thinking of the project participants before and during the project.

The analyst may argue that creating an after-the-fact schedule will allow the analysis to be more precise, containing all the facts of the project. However, there is almost always more than one way to build a project, and the analyst may choose an approach different from the approach chosen by the original planner. Even seemingly small differences in a schedule could affect the results of an analysis.

Using a schedule created after the fact to measure and identify project delay has at least two basic weaknesses: The schedule does not depict the original construction plan and the schedule may include predetermined conclusions concerning delays. There are many ways a construction plan can be represented in a schedule. Preparing one after the fact merely shows the plan the analyst believes was intended. This does not make it correct.

When possible, it is always best to use the contemporaneous project schedules to measure project delay. While the analyst may make very minor modifications to the contemporaneous schedule to account for obvious errors, such changes must be made judiciously. To make this point, consider this judge's decision, which describes the use of the contemporaneous schedules as they existed at the time.

> *In the absence of compelling evidence of actual errors in the CPMs, we will let the parties "live or die" by the CPM applicable to the relevant time frames [Santa Fe, Inc. VABCA No. 2168, 87—3 BCA ¶ 20677].*

WHAT TO DO WHEN THERE IS NO SCHEDULE?

There are instances when contemporaneous project schedules cannot be used to measure the project delay. In these cases, the project schedules either did not exist or the analyst has determined that the contemporaneous schedules did not appropriately depict the plan to construct the project and, thus, would not be a reliable tool to identify and measure the project delay.

When a contemporaneous schedule is not available as a tool with which to identify and measure the critical project delays, the analyst should perform an as-built analysis to identify the critical project delay. An as-built analysis usually starts with the preparation of an as-built diagram. An as-built diagram is prepared using the project's contemporaneous documents. Such documents may include, but are not limited to, timesheets, inspector daily reports, meeting minutes, project photos, and so on. When complete, an as-built diagram should depict the order and durations of the project work activities. The as-built analysis is described in more detail in a later section of this book.

WHAT IS AS-BUILT INFORMATION?

Most, if not all, analysis methods are based in significant part on information that indicates how the project was built. As-built information consists of the reported actual start and finish dates of the Project work activities and the progress made each day on these activities. One of the best places to find as-built information is in the project schedule updates, because the periodic updates typically record the dates that specific activities start and finish. In addition to containing the activities' actual start and finish dates, schedule updates also record the remaining duration of activities that have started but not finished in each update period. Even if the updates contain the project's as-built information, it is always wise to verify information in the updates, using as many independent sources as possible. For example, the analyst might review the project daily reports to verify that specific activities started and finished on the dates indicated in the updates.

Note that the schedule updates do not usually provide information sufficient to determine how much work was performed on an activity each day. However, this can often be approximated by comparing the planned and remaining duration and reviewing other data, such as daily reports and meeting minutes.

If the updates do not provide the information required or if the updates simply do not exist, then the analyst has no alternative but to prepare an as-built diagram, using the contemporaneous project documents. The following documents should be reviewed as possible sources of as-built information:

- Project daily reports
- Project diaries
- Meeting minutes
- Pay applications or estimates
- Inspection reports by the designer, owner, lending institution, construction manager, or other parties making periodic inspections of the project
- Correspondence
- Memos to the file
- Dated project photos

When preparing an as-built diagram, the analyst should document every day that work is recorded for each activity. It is not enough to merely record the start and finish dates. While the start and finish dates are extremely important, the determination of whether work was performed continuously or interrupted will also be significant.

A CONCEPTUAL APPROACH TO ANALYZING DELAYS

While we present several analysis methods in detail later in this book, the following conceptual approach may be used to gain an initial understanding of how to properly analyze delays on a construction project. Also, because the specific steps in each analysis will vary depending on the nature of the available information, the concepts presented in the following figures may also be used as a guide to ensure that the method being used will result in a reliable answer.

The first step in any analysis is to determine the contractor's plan, generally depicted in the as-planned schedule. For purposes of this discussion, a simple, single bar chart network is used to demonstrate the analysis. Because the schedule consists of a single path, this path is the critical path. Fig. 5.1 is the contractor's as-planned schedule for a project.

To determine what occurred on the project, the analyst may create an as-built diagram or rely on the as-built dates from the last submission of the project's CPM schedule. For this example, Fig. 5.2 depicts the as-built or actual performance of the project work.

At this stage of an analysis, there may be a desire to simply compare the as-planned schedule with the as-built diagram, which is depicted in Fig. 5.3, and an attempt to reach conclusions concerning what was delayed.

When we look at Fig. 5.3, the project was planned to have finished on Day 35, but actually finished 30 days later on Day 65. With the knowledge of both the project's planned and actual completion dates, the goal of any delay analysis is to determine why the project finished 30 days late. Clearly, Activity E was added to the project and was the last work to finish. It might be tempting to simply conclude that this new activity and the added work it represented was responsible for the project finishing 30 days late. Fight this temptation.

When analyzing delays, start at the beginning of the project and move through the project chronologically. This will allow the identification of

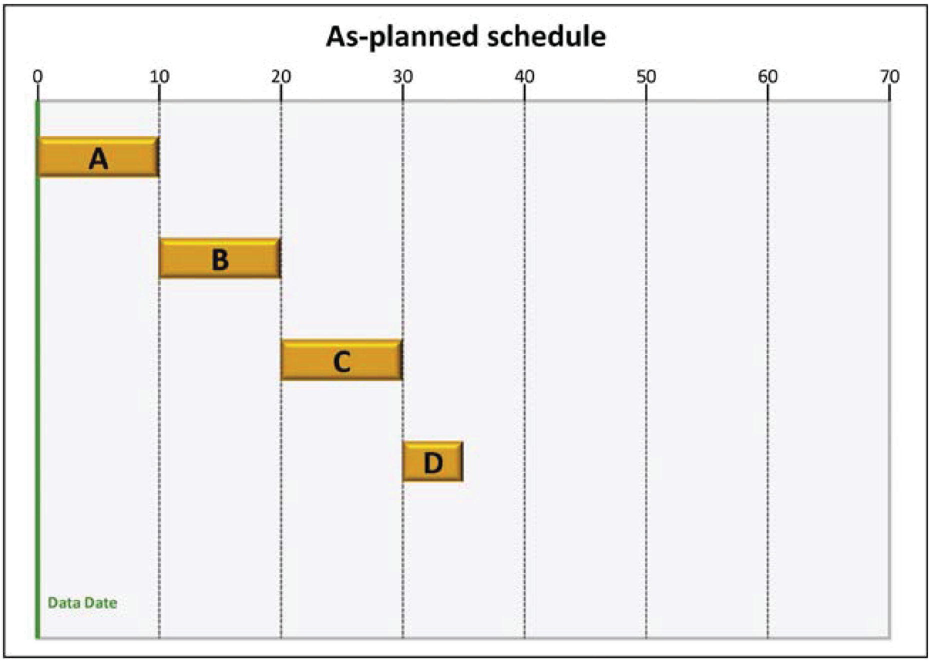

Figure 5.1 As-planned schedule.

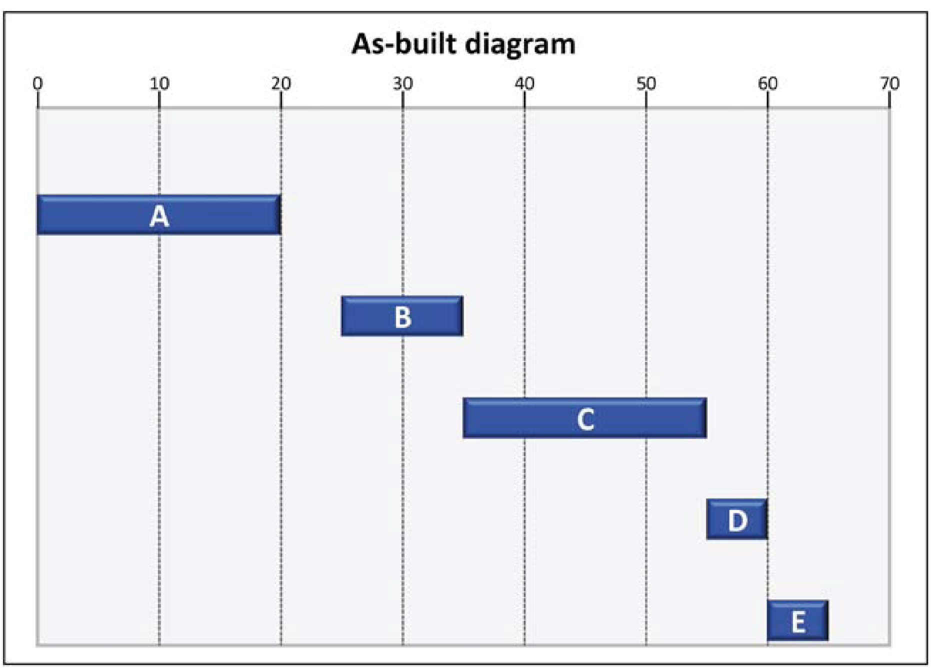

Figure 5.2 As-built diagram.

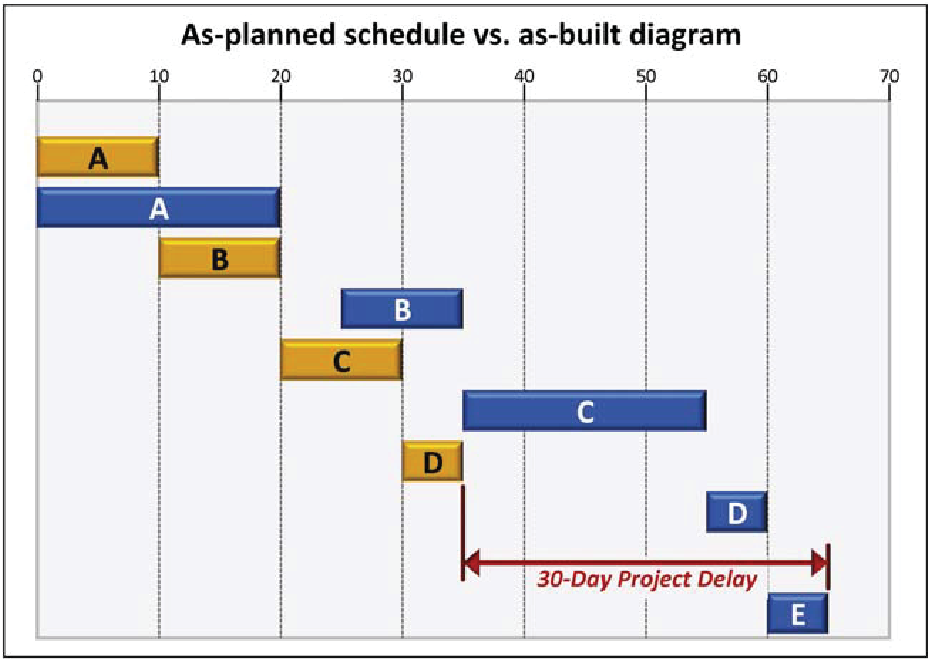

Figure 5.3 Comparison of as-planned schedule and as-built diagram.

each delay as it occurs. Therefore, the analysis will proceed starting with Fig. 5.4.

Looking at Fig. 5.4, start with Activity A, which is the project's first activity and the initial critical activity. The planned yellow (gray in print versions) bar shows that Activity A should have begun immediately and finish on Day 10. However, when comparing Activity A's planned and actual performance, we see that Activity A started on time, but took twice as long to finish than planned. As opposed to 10 days, Activity A took 20 days to complete. The proper conclusion from this comparison is that Activity A was delayed for 10 days as a result of its late finish.

Because an activity delay may or may not be equal to the project delay, it is important to update the schedule to determine the effect that the late finish of Activity A had on the remaining work. Fig. 5.5 depicts the updated schedule based on the actual performance of Activity A.

Note that moving the data date of the schedule from Day 0 to immediately after the completion of Activity A updates the schedule for the remaining work. As a result of the late finish of Activity A, the planned start of Activity B and remaining work have been pushed out and the project was delayed 10 days.

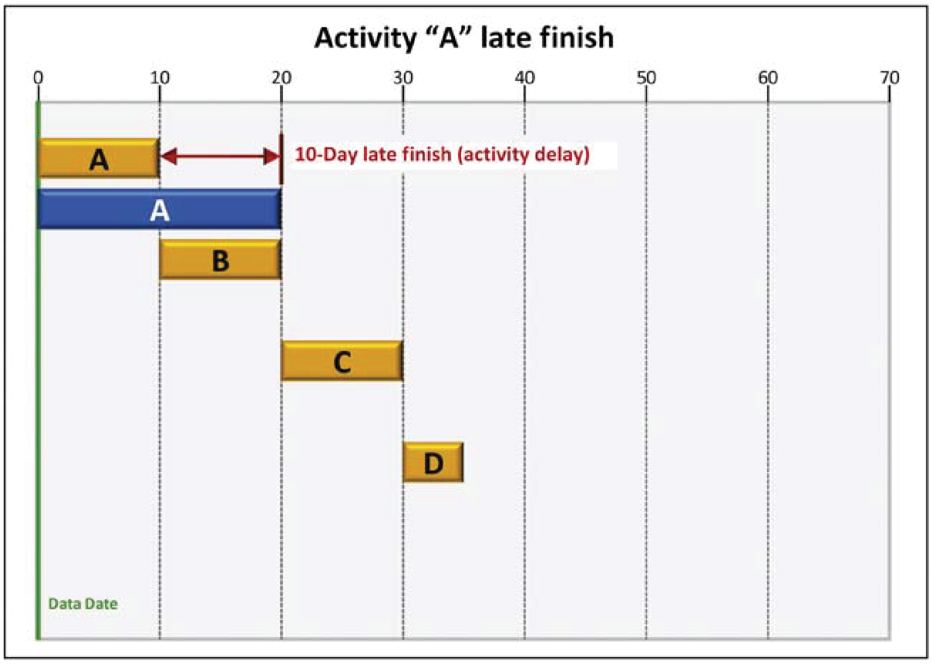

Figure 5.4 Activity A late finish.

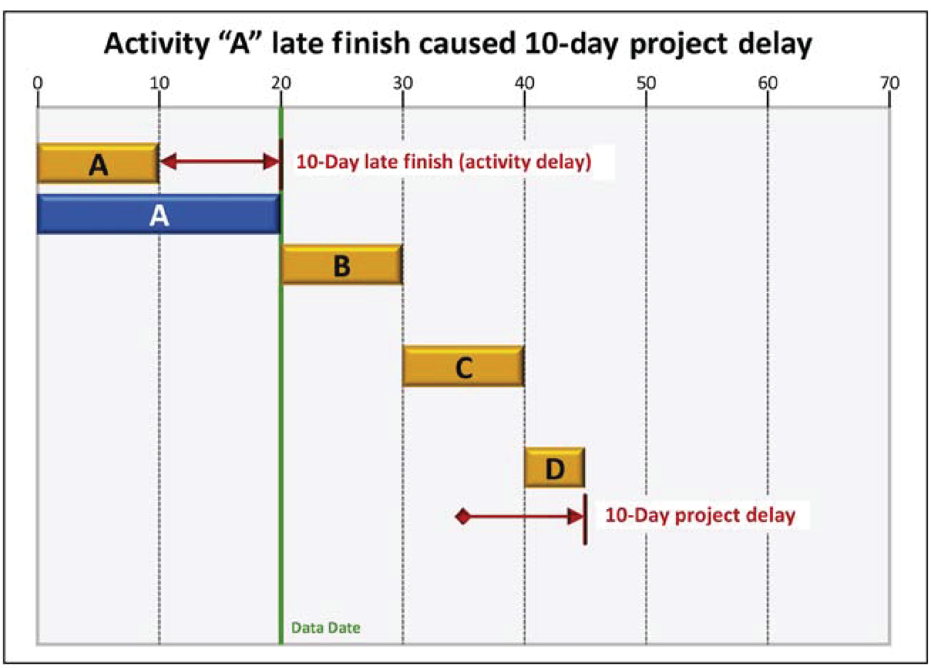

Figure 5.5 Activity A late finish caused 10-day project delay.

At this point, let us stop and consider the delay to Activity A. Activity A is critical and the delay to Activity A is a critical delay. The 10-day critical delay to Activity A happens to also cause a 10-day critical delay to the scheduled project completion date. Think of this critical delay the same way classical physicists thought of matter. It can be neither created nor destroyed. It can be mitigated if the contractor and owner can figure out a way to complete the remaining critical project work more quickly, but this initial 10-day critical delay will never go away.

Note, also, that this 10-day critical delay is based on the change in the forecast or scheduled project completion date. In this case, the schedule becomes the proper measuring tool for the delay. The schedule analyst is putting the same level of confidence in the schedule that the nuclear reactor operator puts into the gauge showing reactor temperature. If the gauge shows the reactor temperature going up, the operator assumes that the reactor is heating up, not that the gauge is broken. Similarly, the analyst assumes that the schedule is correct and that the project has been delayed, not that the schedule is incorrect and the project is likely to finish on time.

Finally, note that in this example, the activity delay and the project delay are equal. That obvious result is because we have simple finish-to-start logic on a calendar with no nonwork days. However, even most simple construction project schedules will have nonworkday weekend days and so it is common for the activity delay and the project delay to differ by a few days.

Fig. 5.5 shows that Activity B was expected to start immediately after the completion of Activity A and finish on Day 30. The next step is to evaluate whether Activity B was completed as expected.

Fig. 5.6 shows that Activity B did not start immediately after the completion of Activity A as expected. Activity B actually started 5 days later than its "adjusted" planned start date. This is the second delay. Activity B was delayed 5 days because it started late. However, this activity then completed within its planned duration.

To determine the effect that the late start of Activity B had on the project's completion, the schedule is updated to Day 35. Fig. 5.7 depicts this schedule update.

Fig. 5.7 shows that the late start of Activity B was responsible for pushing out Activities C and D and, ultimately, delaying the project 5 days. Fig. 5.7 also shows that Activity C was expected to start

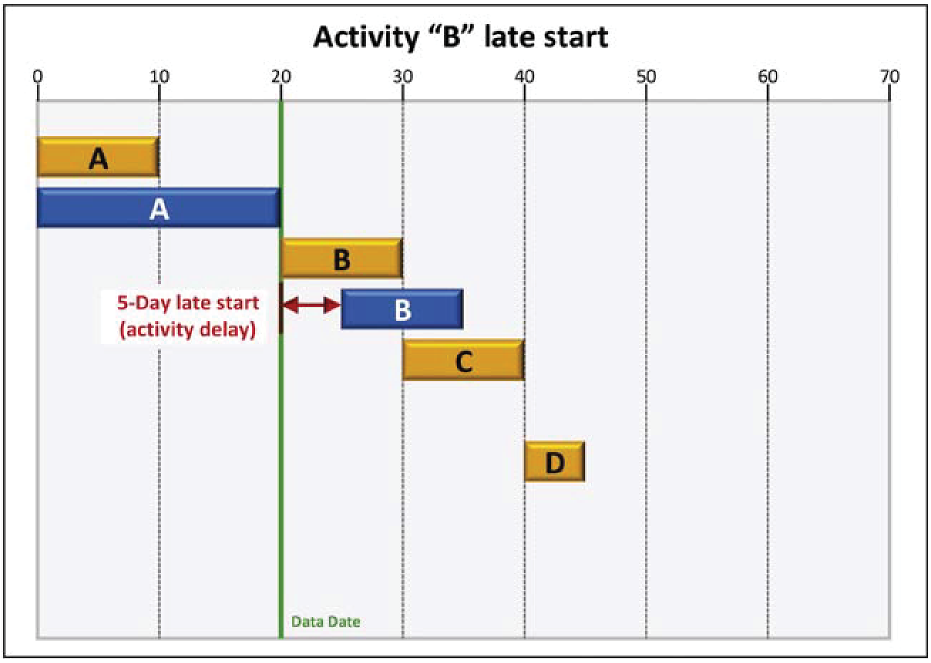

Figure 5.6 Activity B late start.

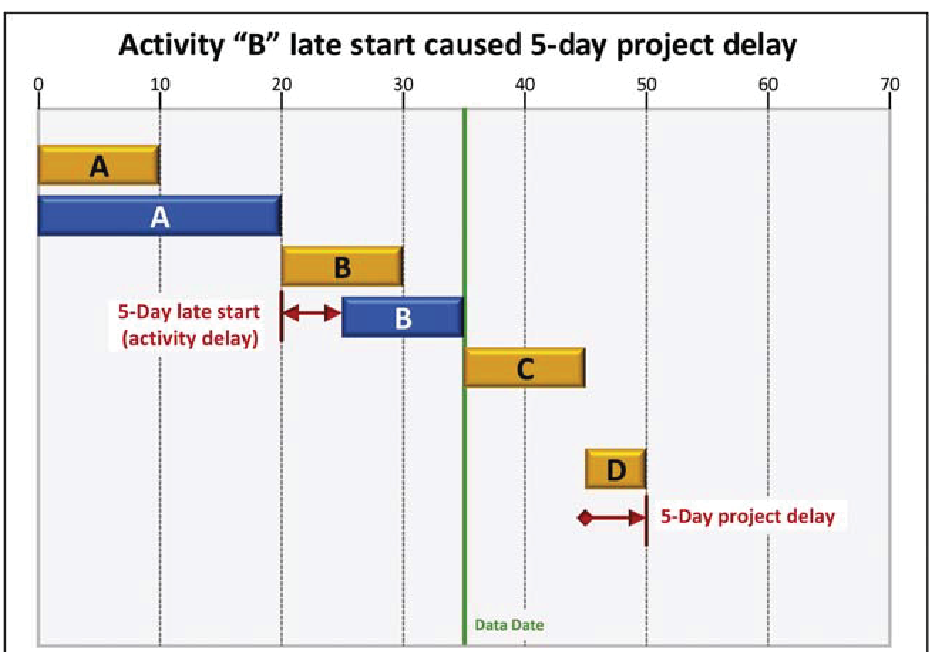

Figure 5.7 Activity B late start caused 5-day project delay.

immediately after the completion of Activity B and finish on Day 45. The next step is to evaluate the performance of Activity C. Fig. 5.8 shows that Activity C was not performed as expected.

Fig. 5.8 shows that Activity C started as expected, which was immediately after Activity B finished, but that it finished 10 days late. Perhaps more importantly with regard to the evaluation of Activity C's performance, Activity C was completed intermittently. Again, to measure the effect that the late finish of Activity C had on the project, the schedule is updated to Day 55. The result is depicted in Fig. 5.9.

Fig. 5.9 shows that the late finish of Activity C resulted in a 10-day project delay.

On Day 55, the owner added work to the project and the parties agreed to add an activity to the schedule to represent the added work. The result is depicted in Fig. 5.10.

Fig. 5.10 shows that after Activity E is inserted into the schedule, the project is now forecast to finish on Day 70, a 10-day delay.

The next step in the analysis is to compare the planned and actual completion of Activity D to determine whether its actual progress caused any project delay. Fig. 5.11 depicts the actual progress of Activity D.

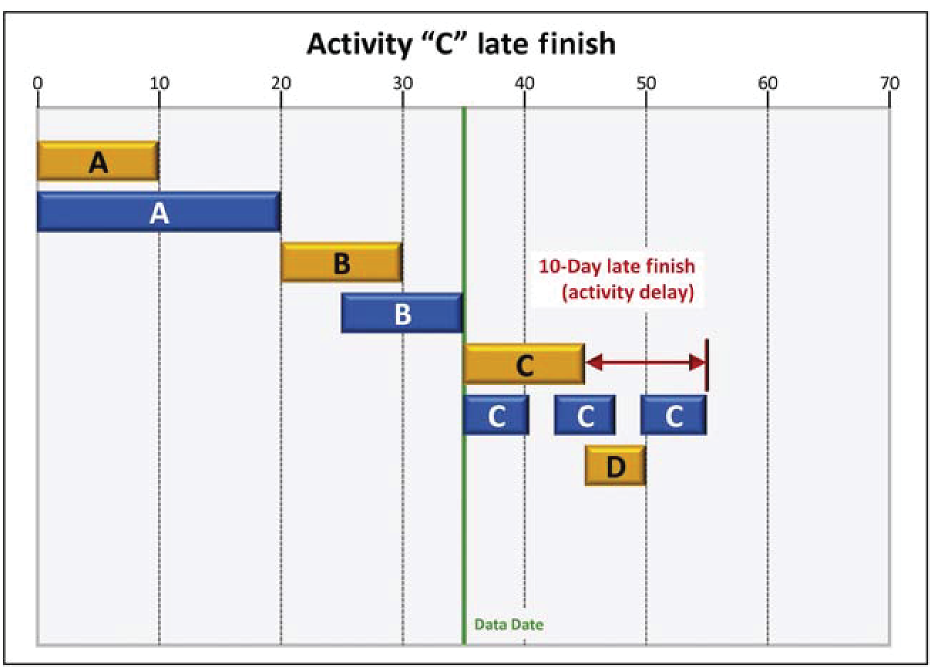

Figure 5.8 Activity C late finish.

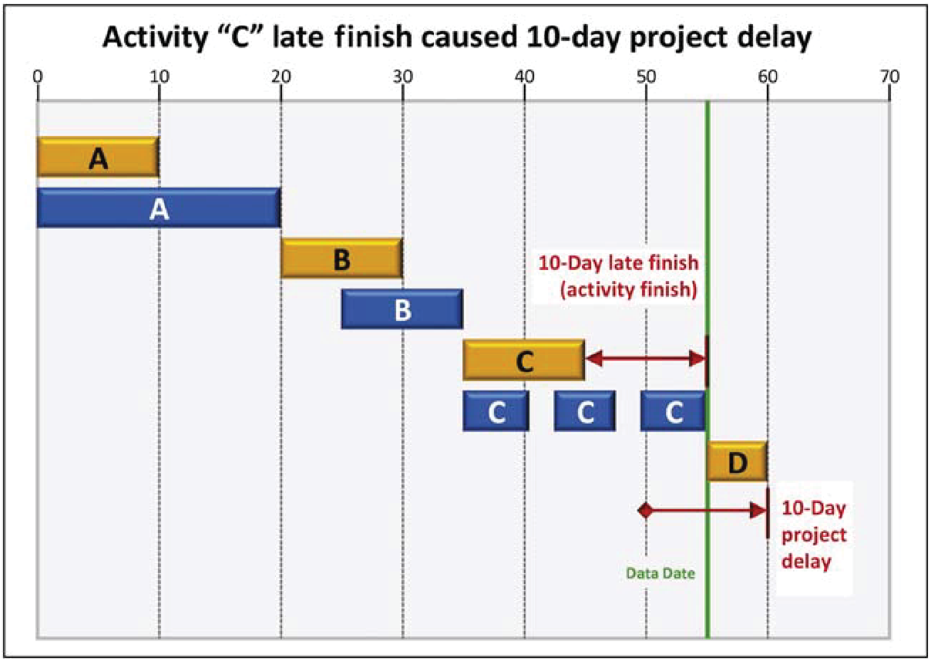

Figure 5.9 Activity C late finish caused 10-day project delay.

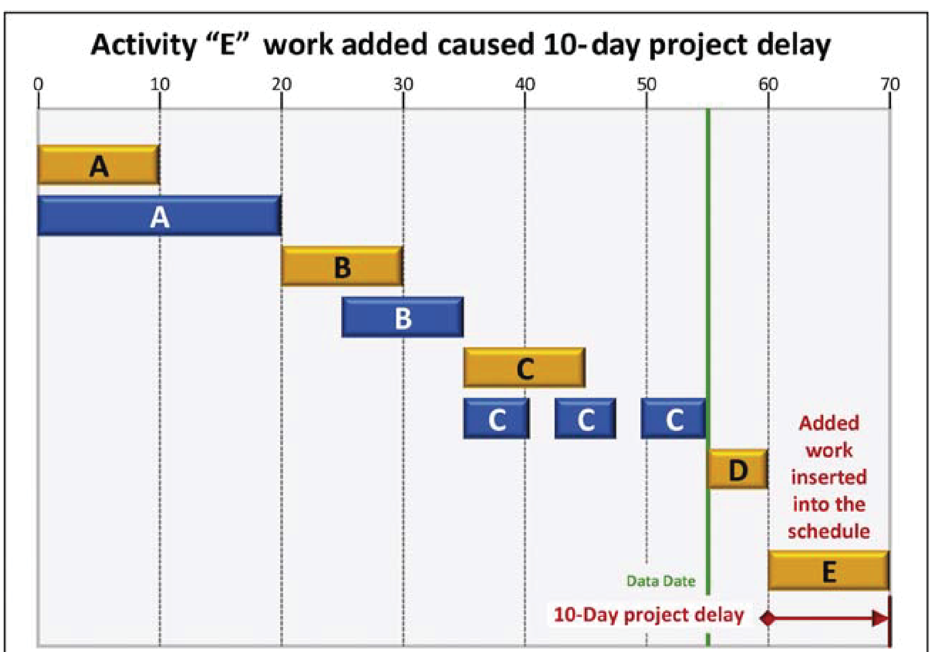

Figure 5.10 Activity E work added caused 10-day project delay.

Fig. 5.11 shows that Activity D started and finished as expected, resulting in no additional project delay. The next step is to compare the planned and actual performance of Activity E to determine whether it was responsible for any project delay. The result of this comparison is depicted in Fig. 5.12.

Fig. 5.12 shows that Activity E was actually completed in 5 days less than expected. As a result of Activity E finishing 5 days early, the project experienced a 5-day savings and the project was completed on Day 65. Lastly, Fig. 5.13 summarizes the assignment of the project delay to the responsible activities.

In one form or another, this stepwise conceptual approach starting at the beginning of the project should be used as a guide in almost all analyses of delays. Note that the precise charting of the as-built information is very helpful when the analyst moves to a determination of the cause of the delay or the liability for the delay. For instance, by knowing that the performance of Activity C was interrupted, as opposed to just taking longer, the analyst can focus on the available project documentation to identify the reasons why the work was performed in an intermittent fashion.

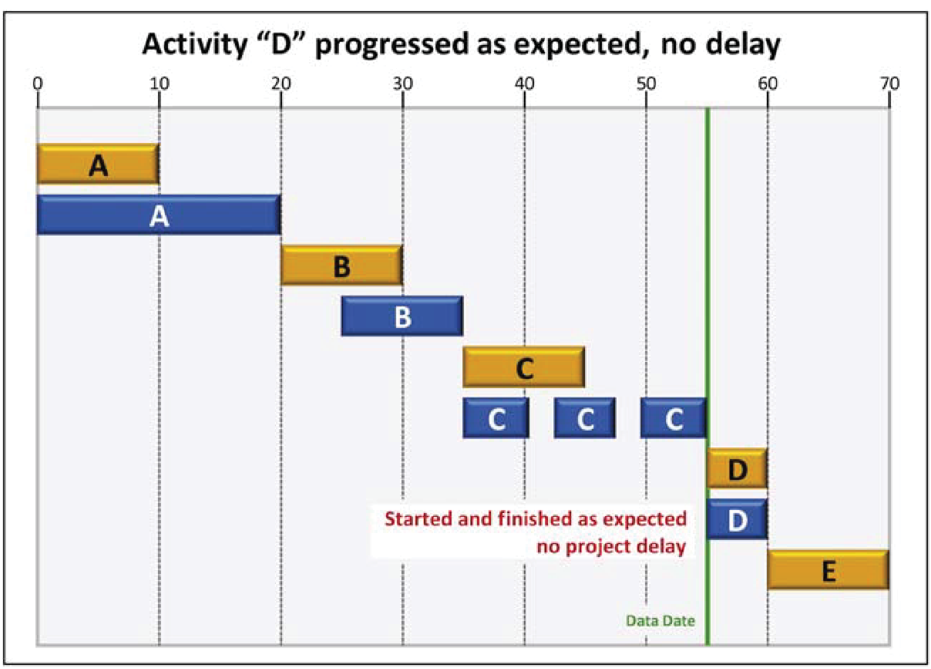

Figure 5.11 Activity D progressed as expected, no delay.

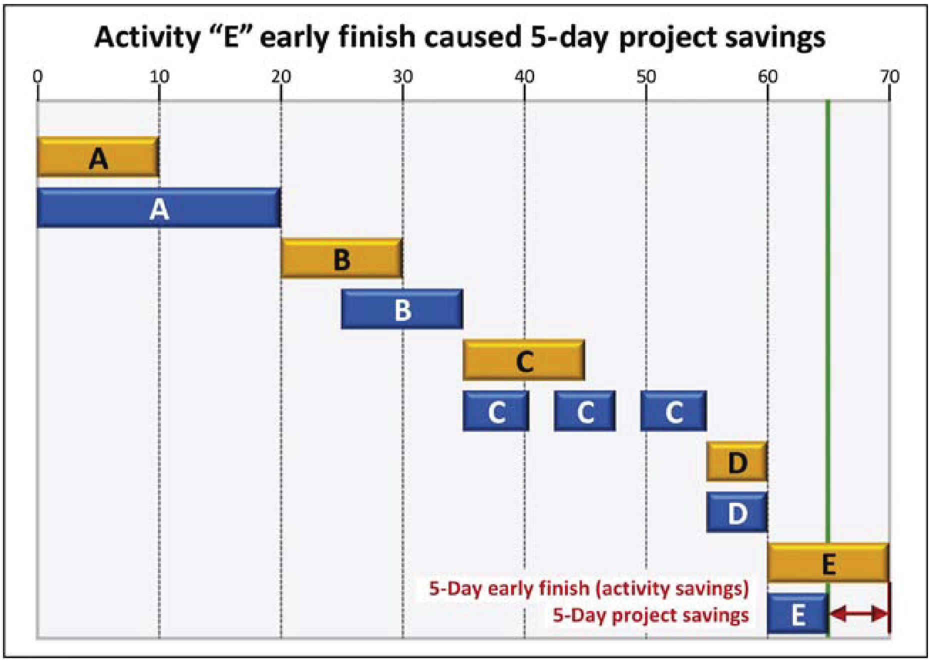

Figure 5.12 Activity E early finish caused 5-day project savings.

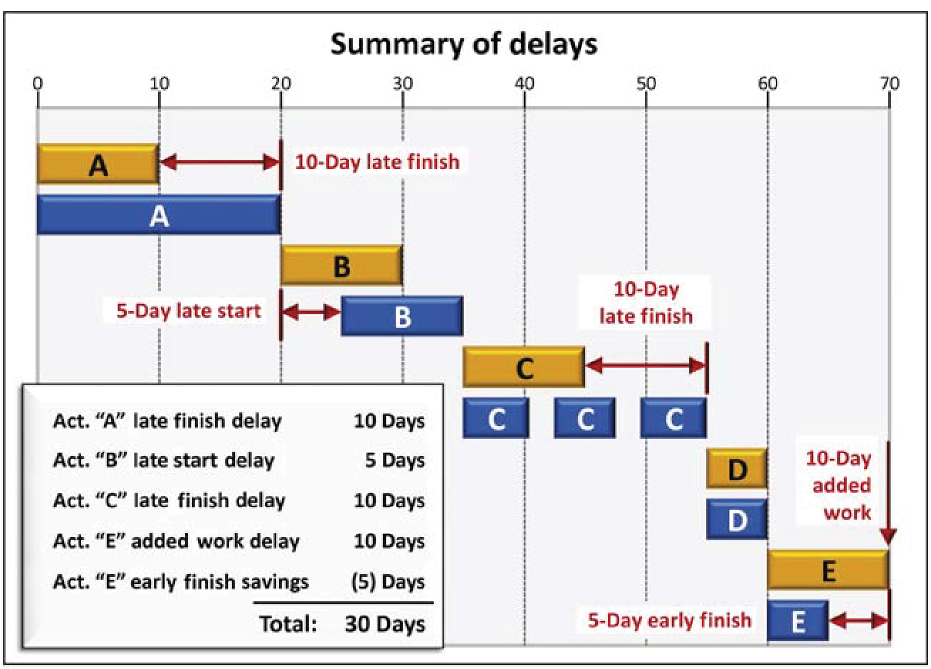

Figure 5.13 Summary of delays.

THE UNIQUE POSITION OF SUBCONTRACTORS

Because the duration of a project can only be extended by delays to activities on the project's critical path, a contractor's performance period can only be extended when the project experiences a critical delay. However, this is not necessarily the case for the performance period of a subcontractor.

While certain subcontractors may have work to perform during the entire project period, it is more typical for a trade subcontractor to have its work become available sometime after the project work has begun and be required to complete its subcontract work before all the project work can be or has been completed. As a result, the trade subcontractor's work may or may not show up on the project's critical path. Still, delays that extend the subcontractor's work will require the subcontractor to be on the job longer, thus, extending the subcontractor's performance period.

For example, a masonry subcontractor may not be able to begin its subcontract brick veneer work until the exterior sheathing has been installed on a building that is expected to take 18 months to construct. The as-planned schedule may show that after the exterior sheathing had been completed on one elevation, the masonry work could begin and would take 3 months to complete, followed by other exterior and interior finish work. Because the masonry work is planned to follow the expected pace of the exterior sheathing installation, the masonry may never show up on the critical path.

Presuming that the exterior sheathing work experiences delays, the exterior sheathing work is more likely to show up on the critical path than is the masonry work. Yet, the masonry work will be delayed because it will not be able to proceed at the planned pace. As a result, the masonry work takes 5 months to complete instead of the planned 3-month period. The mason claims that its performance period was extended by 2 months through no fault of its own. It requests additional compensation for extended overhead costs and other delay damages.

In this example, an analysis of delays along the critical path of the project may not support the mason's request. However, from the facts presented, it is evident that the mason's performance period was extended, and, depending on the provisions of its subcontract, the mason may be able to recover the delay costs caused by others.

If a critical path analysis of the project does not support the mason's claim, what type of analysis should be performed to determine if the mason's claim has merit? In the preceding simple example, the answer appears straightforward. For most subcontractors, however, their work is integrated with many aspects of the project work. Often, the relationships among the various work activities of the prime contractor and the various subcontractors are more complex than the preceding simple example. To complicate matters, when the subcontractor's work is not on the critical path of the project, unless constrained in some other way, it will have float. Therefore, any analysis of subcontractor delays will also involve an examination of the subcontractor's obligations with respect to activity float.

When investigating potential delays to a subcontractor's performance, begin by evaluating the performance requirements of the subcontract. The objective of this evaluation is to determine the period of performance for which the subcontractor is obligated under the terms of the subcontract. Often, a subcontractor is required to perform its work according to the project schedule. Typically, the prime contractor reserves its right to modify the schedule as necessary to complete the work in a timely fashion. The subcontract will then require the subcontractor to perform according to these modifications as well. Because these modifications are not known at the time of the subcontract agreement, there is a certain expectation that the parties have regarding the subcontractor's performance period. This expectation will usually be a product of the particular negotiation that led to the signing of the subcontract.

While the subcontractor typically takes on some risk regarding the prime contractor's right to modify the schedule, this risk is typically not without limits. The contract CPM schedule will identify early and late dates for all of the subcontractor's work activities. When obligated to perform according to the contract schedule, it is reasonable to conclude that the subcontractor is obligated to be on site from the projected early start date of its first activity to the late finish of its last work activity. This conclusion recognizes that the work activities do not need to be performed on the early dates for the project to complete on time. Thus, performance of the work within the early and late date ranges are foreseeable because such performance is, in fact, "according to" the schedule. This remains true, even if such performance affects the continuity of the trade subcontractor's work activities.

The prime contractor, however, may argue that the subcontract allows for modifications to the sequence and duration of the work. Here again, there may be a question as to the degree such modifications are foreseeable. It may be reasonable for the prime contractor to argue that, because it is responsible to the owner to complete the project on time, it must continually assess progress against its plan to complete the work. When the actual progress differs from that planned, it must modify the sequence and duration of future work to ensure an on-time completion. As a result, modifications to the schedule that change the sequence and duration of the subcontractor's work activities within the original project performance period may be foreseeable. Much of this argument, however, will depend on the nature and extent of these changes. Unlimited modifications to the sequence and duration of the work are generally not anticipated by the parties.

Through careful evaluation of the subcontract and the understandings and circumstances leading to the subcontract agreement, the subcontractor's planned performance period can be determined. Unlike the prime contractor's contract performance period, which is generally expressed in the contract, the parties may be unable to agree on the subcontract period of performance. In such cases, the parties will prepare their respective arguments based on the subcontract performance period they believe to be correct.

Once the subcontract period of performance has been established, a comparison to the subcontractor's actual performance period provides a measure of the total delay experienced by the subcontractor. But this is only the beginning of the story. Next, it is necessary to determine the causal link between the actions of the parties and the delays incurred in order to determine if the subcontractor's delays were caused by others.

In order to determine the cause of delays to the subcontract period of performance, it is necessary to determine the critical path of the subcontractor's work. The critical path of the subcontractor's work is the longest path of activities leading from the first work activity to be performed by the subcontractor to the last. This path may consist of some or all of the subcontractor's work activities, as well as work activities performed by others. Because these activities are integrated within the entire schedule network, the analyst cannot simply isolate the subcontractor's work activities and evaluate the paths among these in a vacuum. Many of the subcontractor's work activities will be driven by activities being performed by others, and all of these relationships must be considered in the analysis.

As a result of these complexities, it may not be possible to determine the longest path between the subcontractor's start and end points through an analysis of the electronic schedules. As an alternative, it may be necessary to determine the subcontractor's critical path through a detailed evaluation of the subcontractor's daily work progress. This evaluation is similar to the As-Built Delay Analysis discussed later in this book.

This process begins with the preparation of a detailed as-built diagram that tracks the subcontractor's actual performance. This performance is then compared to the available planned performance information. To begin with, the analyst determines if the subcontractor was able to meet planned durations for its work and, if not, why not. Did the subcontractor provide sufficient resources to accomplish the work? Was the subcontractor given access to the work as anticipated or was it required to perform its work under conditions that differed from those it expected to encounter? Was the subcontractor in control of the pace of the work, or was something else controlling the pace?

It is also necessary to look at the sequence of the subcontractor's work to see if it differed from that planned and, if so, why. As the work progresses, it is also necessary to consider all of the subcontract work remaining and the precedent requirements of that work. For example, if the subcontractor was delayed in one area of the project, was there other available work for it to perform?

By evaluating the subcontractor's as-built work performance moving forward through the project and considering the work that remains, the critical path of the subcontractor's work can be determined in addition to the factors that extended the work along this path.

When a project is managed by a well-thought-out and periodically updated CPM schedule, the analyst has many tools at his or her disposal to help determine the delays to the prime contractor's performance period. To begin with, the contract will usually state the contract performance period, and the longest path through the Project can easily be determined by the scheduling software. However, in the case of delays to the subcontractor's performance period, these tools are less effective. As a result, the analyst must apply a more in-depth knowledge of both the subcontracting process and of the project management process in order to determine the most appropriate way to resolve disputes related to subcontractor delays.