6.6 GOLDRATT'S CRITICAL CHAIN

Much research has been done on scheduling with constrained resources, and the findings verify what was expected—projects are completed faster when there are fewer of them struggling for attention from a limited set of facilities (Adler, Mandelbaum, Nguyen, and Schwerer, 1996). More recently, in the book *Critical Chain* (1997) Eliyahu Goldratt applies his Theory of Constraints—so brilliantly developed in his famous book, *The Goal* (Goldratt and Cox, 1992)—to the constrained resource problem. While Goldratt's focus in the *Critical Chain* is on a single project with multiple demands on a scarce resource, the logic extends to the multiproject case without alteration.

In the following few pages you will note that the exposition focuses mainly on scheduling. But isn't this chapter supposed to be about resource usage? It should be quite clear by now that resource usage and project schedules are inextricably bound together. The technological necessities that force schedules to be ordered in very specific ways simultaneously force resources to be used in very specific ways. To schedule work is also to schedule resource usage. If technology is the prime force behind scheduling the activities of a project, resource availability constrains all solutions to the scheduling problem.

To begin our discussion of Goldratt's approach, imagine for the moment that you are sitting in a room full of people with extensive experience as both project team members and project managers. Now imagine the responses you would hear if the group were asked the question: "What things troubled you most about the projects you have been involved with?" Our experience suggests that the following are typical of the responses that would be offered:

- Project due dates are too often unrealistic.
- There are too many changes made in the project's scope.
- Key resources and data are often unavailable when needed.
- The budget is frequently unrealistic and therefore often exceeded.
- It seems like my project is always in competition for resources with other projects.

One interesting observation is that these same issues are raised regardless of the organizational context. Thus we hear strikingly similar complaints regardless of whether the group is referring to a construction project, a software development project, a project to develop an advertising campaign, or an R&D project.

Based on this, it is not farfetched to conclude that the causes of these problems are generic to all types of projects. As we have discussed throughout this book, project management is fundamentally concerned with effectively trading off performance, cost, and time. Referring back to the earlier list of complaints, it can be seen that each issue deals with one or more of the three primary project objectives.

Given our conclusion that the problems encountered when managing projects are strongly related to the need to trade off one project objective for another, a natural question arises about the extent to which the need to make these trade-offs are caused by human decisions and practices. In other words, can more effective project management minimize the occurrence of these problems? To investigate this issue, let's examine the first complaint regarding unrealistic due dates in more detail.

One way to investigate this issue is to see if we can identify any generally accepted practices that would tend to cause the shared perception of many project workers that project due dates are often set too optimistically. To make our discussion more concrete, consider the three AOA network diagrams shown in Figure 6-21. The primary difference between the three diagrams is the degree of interdependence across the paths. In scenario 1, there is only a single path. In scenario 2, the path B-C-D-E is preceded by three activities A1, A2, and A3. Therefore, the completion of path B-C-D-E

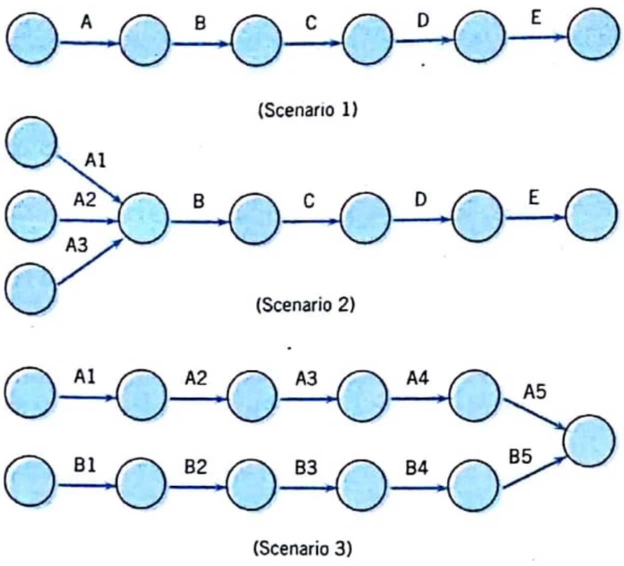

Figure 6-21 Three project scenarios.

depends on which of its three preceding tasks takes the longest. In scenario 3 there are two completely independent paths each consisting of five tasks.

Assume that as project manager you are told that all of the tasks in the three network diagrams require ten days to complete. What completion time would you calculate for each project? If you assume that the activity times are known with certainty, then all three projects would have the same duration of 50 days. If you find this result somewhat unsettling, you are in good company. Thinking about it intuitively, how can a simple project like scenario 1 with a single path and only five activities have the same duration as scenario 2 with three paths and seven activities, or with scenario 3 with two paths and ten activities?

Part of the problem is our assumption that the activity times are known with certainty. To investigate this further, let's assume that all activity times are normally distributed with a mean of ten days and standard deviation of three. The results of simulating the completion of the three projects 200 times each are summarized in Table 6-6.

As you can see from Table 6-6, removing the assumption that the activity times are known with certainty leads to quite different results. Scenario 1's average duration was slightly higher than the 50 we calculated earlier under the assumption of deterministic time estimates. To a large extent with this linear structure and with our assumption of normally distributed activity times, activities that take less than the expected time tend to cancel out the variability of activities that take more than the expected time, resulting in an overall average completion time that is close to the expected completion time for the project. (Remember, in Chapter 5 we discovered that this canceling out rarely happens in the real world, because activities may start late or on time, but rarely start early

Table 6-6 Project Completion Time Statistics Based on Simulating Three Projects 200 Times

	Scenario 1	Scenario 2	Scenario 3
Average	50.4	51.9	53.4
Std. Dev.	7.1	6.3	5.3
Max.	69.4	72.7	69.3
Min.	30.1	36.1	39.3
Median	50.0	51.8	53.1

because resources are usually not available before the activity's EST.) Also observe that the more interdependent scenarios 2 and 3, on average, take even longer than scenario 1 and that their minimum times are significantly longer than scenario 1's minimum time.

Most important, note that while the average completion times of the projects are still close to 50, this is simply the average project completion time after simulating the execution of each project 200 times. That is, approximately 50 percent of the time the projects will be completed in less than 50 days and 50 percent of the time the projects will be completed in more than 50 days under the reasonable assumption that the distribution of project completion times follows a symmetrical distribution. (Note that here we are referring to the distribution of project completion times as being symmetrical, not the project activity times). In other words, had we determined the project duration based on the assumption that the activity times are known with certainty (when they were actually probabilistic), we would incur a greater than 50 percent chance that the actual project duration would exceed this estimate. How would you like to have responsibility for a project that has less than a 50 percent chance of being completed on time? *This example clearly demonstrates how the commonly made assumption of known activity times in practice can lead to quite unrealistic project deadlines*.

It is important to point out that the results would have been even more dramatic had the activities required some common resources. Similarly, the results would have been more dramatic and realistic had a nonsymmetrical distribution been used to model the activity times. Why, you might ask, would a nonsymmetrical distribution more realistically model the activity times? Suppose you scheduled a status meeting to last 20 minutes. Is there *any* chance the meeting will last 40 minutes longer than expected, or 60 minutes? What about 40 minutes less, or −20 minutes?

Estimating Task Times

Based on the discussion to this point and assuming that project workers have a general desire to be recognized for good performance, what do you imagine project workers do when they are asked to provide time estimates for tasks if they will be held responsible for actual task duration? Do you think they give an estimate that they believe provides them with only a 50 percent chance of being met? Or, more likely, do you imagine they inflate or *pad* their estimate to increase the likelihood of successfully completing the task on time? What would you do?

If you are like most people, you would inflate your time estimate. Unfortunately, inflated time estimates tend to create even more problems. First, inflating the time estimate has no impact on the actual probability distribution of completing the activity. Second, what do you imagine happens in cases when a project team member finishes early? All too often, the team member believes that it is in his or her best interest to remain silent about completing activities in less than the allotted time so that future time estimates are not automatically discounted by management based on a track record of early task completions. Moreover, there are sometimes penalties for completing early, such as the need to store partially finished materials because the resources required for the next activity are not yet available. Third, just as things tend to fill available closet and storage space in your home, work tends to fill available time. Thus, the scope of the task may be expanded to fill the available time, as Parkinson's Law dictates.

Perhaps even more dangerous than the inflated estimate becoming a self-fulfilling prophecy is that, after receiving approval for a task based on an inflated time estimate, workers may perceive that they now have plenty of time to complete the task and therefore *delay starting the task*. As we noted in Chapter 5, Goldratt (1997) refers to this as the *student syndrome*, likening it to the way students often delay writing a term paper