Student Syndrome

Did you always study for your exams weeks ahead so you could go to bed early the night before? Did you always write your papers to get them done at least a week before the deadline to avoid the gap in the library where all the books on the topic used to be, and to get to the college computers before everyone else was on them all night? (They did not have computers when I was in college, so this was not a problem for me.) Are you normal?

Well, it is probably not news to you that you are normal, and most people have a tendency to wait until tasks get really urgent before they work on them. This is especially true for busy people in high demand. That is, all of the most important people on whom the Project Manager is counting to get the critical path work done on time.

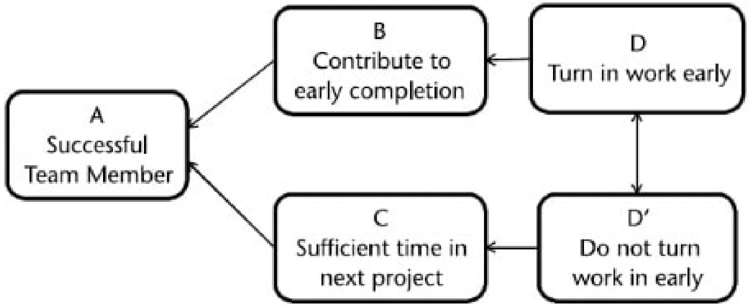

Figure 4.9 One conflict underlying project schedule overruns.

Figure 4.10 shows the typical work pattern of many people. They do less than a third of the work on an activity during the first two-thirds of the activity duration. They do two-thirds of the work during the last third of the activity duration. Where are they more likely to find they have a problem to complete the activity in the remaining time, during the first two-thirds of the effort or during the last third? If they are working above 100% capacity already to complete two-thirds of the work in one-third of the time, there is no chance to keep to the activity duration by a little extra effort. What is the chance that they can recover from an unanticipated problem, like the computer crashes? This behavior is known as *student syndrome*.

Student syndrome behavior results in little chance of seeing the positive side of activity duration variation. The effects described above make it unlikely we could take advantage of positive variation, even if we did see it. No wonder projects rarely complete early. The reality is that relative activity duration normally shows a very skewed distribution, with a mean well above the most likely activity time. This is one reason why we often see overruns on activity time but rarely see underruns.

Most project management guidance recommends that Project Managers use an early start schedule. This means they start all of the noncritical path activities earlier than is necessary to meet the schedule date. People working on those activities know that there is slack in their activity. How do you think this influences the urgency they feel in working on the activity?

Anchoring

A more technical description of the above two behaviors is to consider them both as instances of the psychological cognitive bias called anchoring (Kahneman, 2011). Much psychology research confirms the behavior. The mere fact of presenting a number to people causes behavior in the direction of that number. For CCPM the numbers are estimates of task duration or the finish dates of tasks in the schedule. Presenting a task finish date can cause either of the behaviors to try to complete the task on that date and not before. I call this date-driven behavior and it includes both the effects described anecdotally by Parkinson's law and student syndrome.

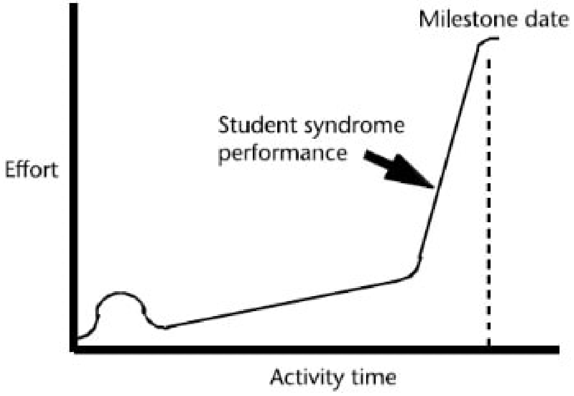

Figure 4.10 People perform most activities, and most people follow the student syndrome performance curve.

4.3.3Multitasking

Now let us assume that the schedule system demands that resources start on activities as soon as possible and report the task start to the Project Manager. Let us assume the person splits their time during the day evenly to three assigned activities. When do they complete? If we assume that there is no time lost from dropping each activity every day and having to get back into it, then none of the activities complete until the third week. Multitasking has increased the activity duration for all three projects to three weeks. They have delayed throughput on the first project for two weeks and on the second for one week.

The multitasking problem is actually much worse than just multiplying by the number of tasks for two powerful reasons. First, a growing body of research shows that each time one switches from working on one task to another task, some time is lost in making the switch and getting up to the previous level of productivity on the new task. Some research suggests this time can be 15 minutes or more for intellectual tasks. It might be even longer for physical tasks. The lost time can reach 40% of productive time. This lost time is pure waste. It is system capacity put to waste. Figure 4.11 illustrates a more realistic comparison of focusing versus multitasking.

The second problem with task switching is that errors often happen when people shift from one task to another. The organizations that have measured the quality defect rate before and after Critical Chain have shown quality defects to plummet, in some cases by 50%. Quality defects also require resource attention for repair, thus further reducing productivity.

Most people think of multitasking as a good way to improve efficiency. It ensures everyone is busy all of the time. Often, I have to wait for inputs or for someone to call back before I can get on with a task. Multitasking makes good use of this time.

Dr. Goldratt demonstrated in *The Goal* how focus on local efficiency could damage the overall performance of a system. He used the example of robots, which were operated all of the time to show high efficiency. In the case of production, this leads to producing excess inventory, and may "plug" the constraint with work not necessary for current orders, increasing operating expense and delivery times with no positive benefit to the company as a whole.

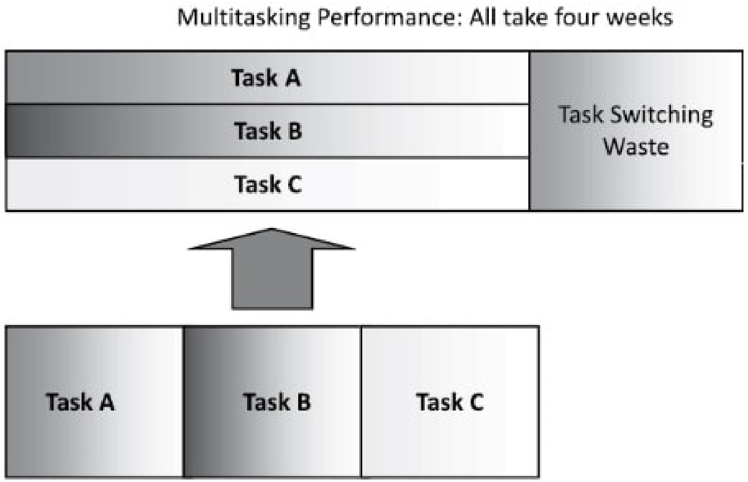

Figure 4.11 Multitasking delays all projects. It also justifies using the longer task times in future plans.

While most people acknowledge the facts above, many argue, "It's just not realistic to do otherwise. We have to satisfy multiple needs." They agree with logic demonstrating that multitasking is a very poor (perhaps the worst) way to meet multiple needs. They acknowledge that it deliberately lowers their personal throughput contribution. They will also agree that leaving and returning to tasks usually impacts the total time necessary to complete the task and often the quality of the product. Nevertheless, many people find it extremely difficult to change this behavior. Purveyors of time management tools work to resolve this conflict at the personal level.

If multitasking is a normal way of business in a company, three or four weeks becomes the normal task duration for this task. Performance data supports this inflated task duration. If this is a critical chain task, the practice directly extends the duration of the project. Most companies admit to encouraging extensive multitasking.

Peter Marris (1996) contended that behavior such as multitasking is a social effect of the more powerful using the less powerful to shield them from uncertainty. In other words, management takes advantage of the lower level resources in the organization by creating the pressure that leads to multitasking.

4.3.4 The Core Conflict Leads to Undesired Effects

You can combine the three conflicts to obtain the underlying core conflict leading to all three conflicts examined. Because the conflicts derived from the three starting undesired effects, resolving the core conflict should have a desirable impact on all three of the undesired effects analyzed. As the project system is a connected system, the core conflict may contribute to the other undesired effects as well.

Figure 4.12 illustrates development of the core conflict. The goal of the three conflicts is common: project success. The top path of the cloud illustrates the logic that leads each individual to work toward his or her own success. To have a successful project, each task must be performed as planned. For each task to perform as planned, each task performer must do whatever individual task success demands.

The lower path illustrates the logic that leads to working towards project success. To have the project succeed, each part of the project must contribute to overall project success. To contribute to overall project success, each task must subordinate to the overall project.

This core conflict is an example of the common conflict referred to by Dr. Deming where improving parts of a system does not necessarily lead to an effective system. It is the conflict identified as a principle in TOC: an optimum system cannot have each part of the system as an optimum. Worse yet, the core conflict sets up a win-lose situation between all of the project workers and project management. No wonder that projects are so stressful to all concerned. No wonder so many projects fail.

Figure 4.13 illustrates how the core conflict leads to all of the undesired effects. This implies that the core conflict is a high leverage part of the project system. A solution (new theory) that resolves the core conflict differently can influence the whole system in a way that tends to move the undesired effects to their desirable counterpart.

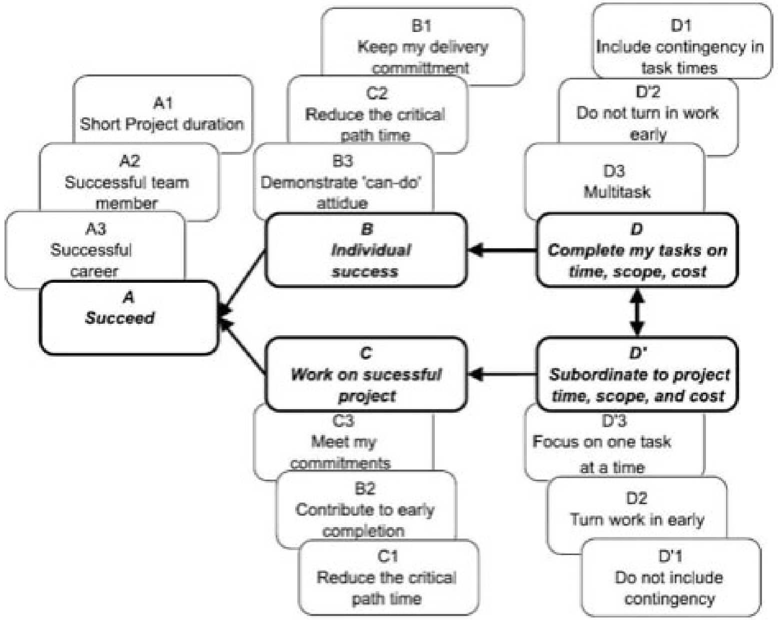

Figure 4.12 The core conflict underlies all three conflicts.

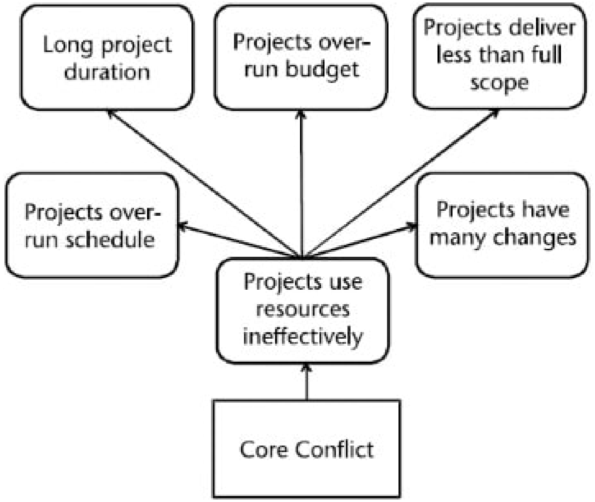

Figure 4.13 The core conflict leads to all of the system undesired effects.

The logic illustrated by Figure 4.13 is incomplete. It is only a notional connection between some part of the core conflict and the undesired effect. If you accept that the core conflict underlies most or all of the undesired effects of the project system, you may be willing to consider the beginning of the solution direction.

4.4Towards Desired Effects

4.4.1Resolving the Core Conflict

Resolving the core conflict requires identifying one or more assumptions that can be made invalid by changing the system. Assumptions underlie each arrow of the core conflict diagram. The Critical Chain method arises from attacking the assumption that adding contingency to each task is the only way to manage uncertainty.

One element of resolving the core conflict must be to correct for the behavior elements: multitasking, Parkinson's law, and student syndrome. The solution to it is the first new rule: focus. The new project delivery system must enable people to focus on one task at a time until they complete it. They must be allowed to limit their personal WIP. While it helps if it is the right task to focus on (more on what that means later), when you eliminate multitasking, all of the tasks you were working on finish sooner than they would with multitasking because of eliminating the task nonworking time and the wasted time of task switching. So even if you work on tasks in the wrong sequence, all (on average) still complete sooner than they would have with multitasking. You will also make fewer errors.

Dr. Goldratt was uniquely positioned to develop the Critical Chain solution for projects. The Critical Chain solution comes from recognizing that the variation in task performance and dependent events is at the root of the behavior of the present system. He had tremendous success in applying the solution for production management described in *The Goal* (Goldratt, 1984). He knew that, in most cases, the uncertainty in project duration estimates is much

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Dr. Goldratt was uniquely positioned to develop the Critical Chain solution for projects. The Critical Chain solution comes from recognizing that the variation in task performance and dependent events is at the root of the behavior of the present system. He had tremendous success in applying the solution for production management described in *The Goal* (Goldratt, 1984). He knew that, in most cases, the uncertainty in project duration estimates is much larger than the variation in production processes. He knew that in many cases the task dependencies in projects were equal to or greater than the dependencies that exist in production. It is natural that he would look at projects from this perspective to find the assumption to attack.

Goldratt describes the impact of variation and dependent events by the saga of Herbie in *The Goal*. He used the scenario of a troop of Boy Scouts on a hike through the woods. The trail is narrow, so the scouts cannot pass the one in front. As they hike, the line grows longer and longer. Alex Rogo, our hero in *The Goal* and the troop leader for this weekend, realizes what is happening. The speed of the Boy Scouts is not the same. There are statistical fluctuations in how fast they walk. They are dependent on the scout in front of them, though, because they cannot pass. These fluctuations cause the length of the line to grow continuously. Herbie turns out to be the slowest scout, the constraint. The gaps in the line compare to inventory in a manufacturing plant.

For a project the gaps in the line of Boy Scouts compare to time. If the next resource is not ready to start when a predecessor activity completes early, the project loses time. We lose the positive variances in statistical fluctuations. This is like a faster boy behind a slower boy; he can catch up, but not pass. The line grows in length. This is worse than the manufacturing case. In manufacturing, they eventually use conservation of time.

The direction of the solution that Goldratt proposed follows from his TOC production solution. The first step is to identify the constraint of the project system. His focus on throughput led him to focus on the time it takes to complete the project. The longest path through the project is the evident constraint. At first look, this is the critical chain.

How then is the critical chain exploited? Dr. Goldratt was a Ph.D. physicist. He knew statistics and knew a lot about the "cloudy" behavior of much of reality. He knew that the only way to take advantage of our statistical knowledge is through dealing with numbers of events. Deming and Shewhart (Shewhart, 1986) before him had pointed out that science could not make predictions about a single instance of a statistical event. This leads to a very simple (in retrospect) insight: concentrate the uncertainty for many of the tasks of the project at the end of the project in a buffer. The buffer has a direct counterpart in his production solution where buffers of in-process inventory are strategically placed in front of machines to prevent them from running out of work. This solution implements Rule 2: Buffer.

Concentrating contingency in the buffer creates two significant bonuses. The first bonus is a shorter schedule. It is a mathematical fact the variances of the sum of samples from a series of independent distributions add. The variance is the square of the standard deviation. The standard deviation is proportional to the amount of variation in a single task. In other words, the uncertainty in the sum of tasks is the square root of the sum of the squares of the individual variations. While attempting to protect the completion date of each task in a project, each task had to include its own allowance for uncertainty. These allowances add up along the path. When we take these allowances out of each task and put them at the end of the path they add as the square root of the sum of the squares, a much smaller total amount. Figure 4.14 illustrates how this works for a very simple case. The reason for this is evident. Some of the tasks should overrun, and some of them should underrun. The distribution of the sum need not be as large as the sum of the individual variations because some can cancel out if you can eliminate Parkinson's law and the student syndrome.

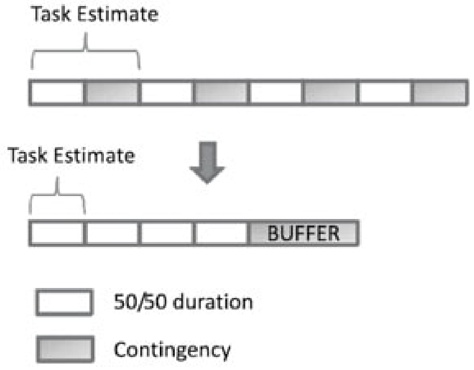

Figure 4.14 Concentrating contingency at the end of the path requires less total project time.

A second statistical fact comes into play with this strategy. The central limit theorem of statistics states that the distribution of samples from a variety of independent distributions tends towards a normal distribution. A normal distribution is a symmetrical distribution. It does not have the long tail to the right that many individual task distributions may have. This means that concentrating contingency at the end of a path reduces the likelihood that it will be overrun by a large amount.

A key part of the direction of the solution Goldratt proposed uses average task completion times in the schedule and adds an aggregated buffer at the end of the schedule for overall project contingency. Mathematically, the mean for each task duration is the average duration that sums along a path. The project buffer is one part of the second of the three new rules introduced in Section 2.8.

4.5Solution Feasibility (Evidence)

Using the scientific method as the theory of knowledge leads to selecting the preferred theory through critical discussion and test. Comparing Critical Chain to CPM shows more content in the Critical Chain theory because it:

1.Provides an explicit method to manage common cause uncertainty.
2.Explicitly resolves the resource constraint.

Popper (1976) noted that a new theory should contain and explain the old theory. With unlimited resources, the critical chain is the same path as the critical path. With a resource constraint, the critical chain is an acceptable solution to the resource-leveled critical path. Thus, Critical Chain contains the critical path solution.

Popper suggested that the primary method of testing a new theory be through critical discussion. This discussion checks the new theory against the old, looking for logical deductive reasoning and evidence supporting the suppositions (assumptions) made in the new and the old theory. Summarizing the reality of the scientific method, Popper stated (Popper, 1976):

> (1) Induction, i.e., inference based on many observations is a myth. It is neither a psychological fact, nor a fact of ordinary life, nor one of scientific procedure.
>
> (2) The actual procedure of science is to operate with conjectures: to jump to conclusions—often after one single observation…
>
> (3) Repeated observations and experiments function in science as tests of our conjectures or hypotheses, i.e., as attempted refutation.

This chapter developed the reasoning behind the way Goldratt defined the problem with the current theory. It does not explain the jump to his proposed direction for the solution: improved management of uncertainty. It is unlikely that others without his

> conjectures: to jump to conclusions—often after one single observation…
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This chapter developed the reasoning behind the way Goldratt defined the problem with the current theory. It does not explain the jump to his proposed direction for the solution: improved management of uncertainty. It is unlikely that others without his knowledge and experience could have made the same jump. The original PERT method and subsequent work with project simulations provide evidence that others were aware of the uncertainty problem.

The current knowledge base lumps the uncertainty in predicting each project task in the area of risk management, adding evidence that people understand the need to deal with it. However, none of the current solutions makes uncertainty management part of the basic project system in the manner of Critical Chain. My approach to CCPM clarifies that buffers serve to manage common-cause variation, while conventional deterministic risk analysis and management handles potential special-cause variation. This is one way CCPM brings the power of Six Sigma and TQM to Critical Chain. Figure 4.15 illustrates the intention that the new solution direction will eliminate all of the UDEs with the current system.

Critical Chain applies buffers to resolve the reasons for schedule overrun caused by the reality of statistical fluctuations (uncertainty or variation) and dependent events. The CPM theory does not address this reality; it uses deterministic durations, starts, and stop dates for activity in the schedule. Combining this technical assumption with human behavior leads to schedule overrun. Schedule overrun leads to cost overrun and reducing the delivered scope. Perhaps most importantly, the new theory explains how the CPM theory, through the win-lose approach to task scheduling, causes much of the psychological harm in project systems.

The resource constraint is every bit as real as the task input constraint. The resource is as necessary to complete the task as the completion of the predecessor task. The CPM assumes that an acceptable solution to the resource constraint is to first find the unrestrained critical path and then assess the impact of the resource constraint. Put another way, determination of the critical path assumes that resources are not the constraint. Alternatively, it assumes infinite resources. We could find no references describing the reasoning behind this assumption. Goldratt found it easy to notice this implicit assumption because finite resource scheduling was an explicit assumption in the production system models with which he had worked.

Some users of CPM have asserted that the resource constraint need not be as real as the technical constraint. That is, for many pieces of work, you simply cannot change the task sequence; you have to put in the foundation before you place the equipment, or you have to remove the equipment before you can reinstall it. However, one often can put resources on overtime, including extended work weeks, or elevate the resource through a variety of approaches. This does not conflict with CCPM, because the schedule maintains the technical sequence of tasks. All tasks require both the technical predecessor and the resource to work. CCPM does not preclude using alternatives to elevate the constraint.

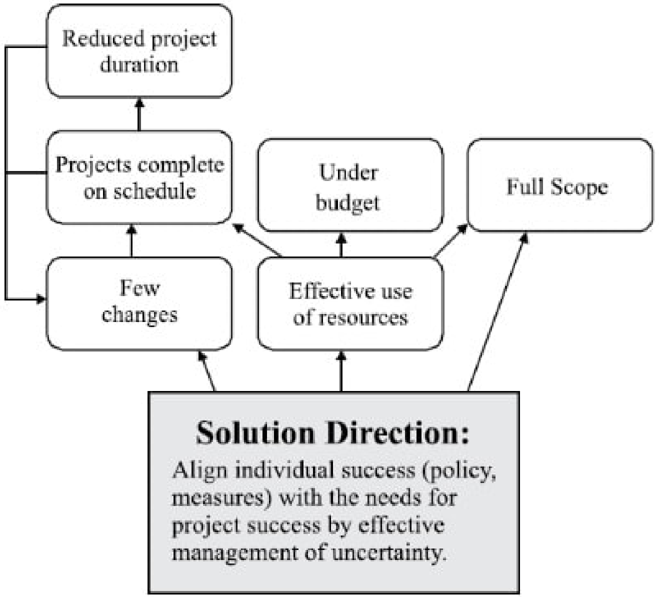

Figure 4.15 The new solution direction reverses all UDEs.

This chapter demonstrated that the CPM usually fails to identify the real constraint to the project (resources). It is a simple and logical step to define the critical chain as the combination of the two potential constraints on the longest path to complete the project.

Chapter 2 presented selected successful evidence that the Critical Chain method creates the desired effects. (It is selected in the sense that it is not an exhaustive listing; this does not mean we selected only the positive results.) By this time, thousands of projects of different types, in different businesses, and in cultures around the world have successfully applied Critical Chain. However, there are cases where implementation failed to achieve the changes necessary for Critical Chain, and the project system continued to operate the old way. Chapter 11 addresses how to avoid this.

4.6Multiproject System

The discussion above considered the direction of solution for a single project: the critical chain. However, there is not a critical chain for multiple projects. We have to reidentify the constraint to obtain the direction of solution for a multiproject system. Where the critical chain forms the constraint for a single project, something else must constrain the throughput of a multiproject system because there is no critical chain for multiple projects. Changing the constraint changes the direction of solution.

Considering the constraint of the multiproject system from the TOC perspective suggests that there must be a bottleneck to the flow of all of the projects. Most Critical Chain practitioners have come to call this the capacity constraint. It was originally thought of as a single resource shared across the multiple projects. If all of your projects share a common limited-supply resource, that can still be an acceptable way to think about it. The large variety of project systems that do not share a common resource across all the projects has led to a different way of thinking about the multiproject constraint. Now there is some agreement that the constraint is simply too much WIP: too many projects have been started and not finished. Excess project WIP also causes pressure on resources to multitask only now on tasks from multiple projects. Also keep in mind that nonproject work puts demand on resources, further increasing the pressure to multitask.

Little's law (Little, 1961) identifies the relationship between the throughput (*T*) of a system, the WIP (*W*), and the cycle time (*C*) for individual projects through the system. Although well known for production system, the applicability of Little's law to multiproject systems came from practitioners of Critical Chain, likely because these practitioner followers of Eli Goldratt had their background in production systems. Little's law is:

$$T = W/C$$

While Little's law is quite simple (and obviously dimensionally correct), using it is not intuitive. The equation suggests that the way to increase T is to increase W. Just the opposite is true. Lean manufacturing found that increased production and flexibility occurs with reductions in W: just-in-time production flow with an ultimate goal of single-piece flow.

Little's law is a single equation containing three unknowns. You may recall from algebra that solving for three unknowns requires three equations. In this case, the equation of most importance is the one that relates W and C. In contrast to the linear nature of Little's law, the relationship between W and C is very nonlinear. That is, over some ranges, small changes in W can cause large changes in C. Queuing theory provides just such a relationship. Figure 4.16 illustrates the queuing curve with the axes relabeled to illustrate the relationship between W and C. As Little's law derives from queuing theory, this seems like an appropriate relationship.

Examination of the figure illustrates that as WIP increases, the cycle time increases nonlinearly, up to infinite cycle time at a WIP equivalent to a resource utilization of 1. At relatively high levels of utilization (the right side of the curve), small changes in utilization yield large changes (reductions) in cycle time. Thus, reduction in WIP appears to be the appropriate direction of solution for the multiproject system.

The solution to WIP reduction is to Pipeline: the third new rule (see Section 2.8). Lean practitioners call it demand leveling. While the critical chain performed demand leveling within a single project, pipelining causes demand leveling at the multiproject level. Chapter 8 continues the discussion for the multiproject system.

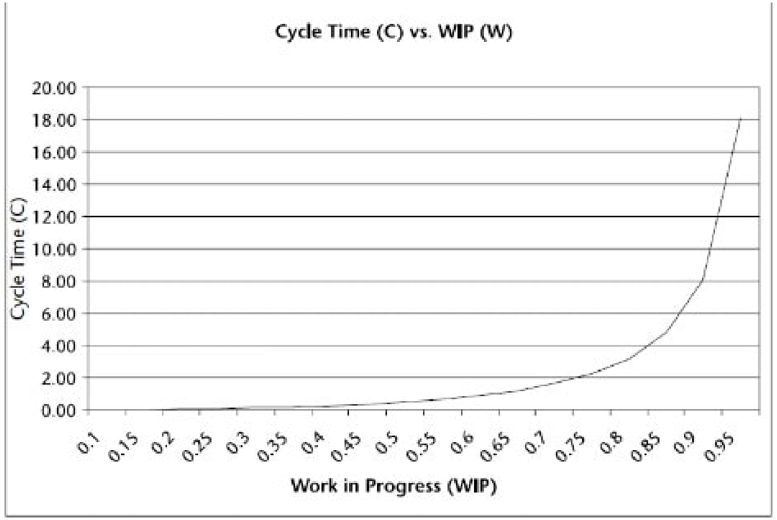

Figure 4.16 The relationship between WIP (WIP/Capactiy) and cycle time (**C**) in a project system.

4.7Execution

While the above discussion addressed human behavior issues during project execution and proposed a direction of solution to enable effective focus on one task at a time during execution, it does not directly enable that focus during execution because variation will cause actual demand to fluctuate compared to baseline schedules created with the above solutions. Thus, the full solution requires tools to enable focus on the right task during execution.

4.8Determine What to Change to

Resolving the core conflict provides a necessary change to the system to begin to move towards the desired effects. The desired effects for the project system, derived from the current reality undesired effects, are:

1.Projects always complete on or before the scheduled completion date.
2.Projects complete within their budget (and sometimes show cost reduction).
3.Projects always deliver the full scope.
4.Projects have few changes.
5.Projects have needed resources without internal fights.
6.Project durations get shorter and shorter.
7.All projects complete.
8.Project work creates win-win solutions for all stakeholders.
9.Project workers are enabled to focus on one task at a time and complete it before moving on to another task.

The changes to resolve the core conflict provide a method to manage uncertainty and enable focused work. The changes acknowledge the