TEACHING CRITICAL CHAIN PROJECT MANAGEMENT: THE ACADEMIC DEBATE AND ILLUSTRATIVE EXAMPLES

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DRAFT, revised 12 March 2011

Abstract

In recent decades, the project scheduling practices known as Critical Chain Project Management (CCPM) have been successful in industrial applications, yet remain a subject of disagreement among scholars and sporadically taught in business schools. The purpose of this paper is to assess what aspects of CCPM are appropriate in operations courses, whether dedicated project management classes or broader introductory operations management. To answer this, we survey academic literature on traditional project management problems that gave rise to CCPM to understand if these issues are real. We also examine if the CCPM methodology should, according to scholars, correct these problems, and survey project success stories attributed to CCPM. We conclude that CCPM is an appropriate project management methodology for student consideration on the basis of motivating critical thinking—especially about behavioral issues—rather than formal scientific proof of its merit. In so doing, we survey teaching resources as well as articles in the trade press on the subject. We then present a sequence of numerical practice problems that are designed to motivate further critical reflection about CCPM. Throughout are a number of open questions about CCPM that the academic community has not yet answered that instructors should keep in mind.

1. INTRODUCTION

In traditional project management practiced in most industries and taught in most business schools, it is assumed that a sequence of tasks in a single project defines the critical path. In Critical Chain Project Management (CCPM), however, a sequence of resources, called a critical chain, may require a task sequence that can exceed the critical path’s duration. To account for a project’s critical sequence, scholars and practitioners introduced resource-constrained project scheduling methods, perhaps as early as Wiest (1964). However, compared with traditional
critical path methods, CCPM has three fundamental differences: cultural changes in milestone accountability and thus task duration estimation, the employment of safety buffers, and the elimination of multitasking and resource conflicts (Watson 2007, p. 397).

The CCPM methodology was borne out of Goldratt and Cox’s (1984) so-called Theory of Constraints (TOC) for capacity planning. According to Watson (2007, p. 396), TOC-based project management was introduced at the 1990 International Jonah Conference and became better known after Goldratt’s (1997) *Critical Chain*.


As CCPM gained exposure and acceptance, scholars examined its merits. See for example, Balakrishnan et al. (2008), Cohen et al. (2004), Herroelen & Leus (2001), Herroelen et al. (2002), Lechler et al. (2004), Maylor (2001), Rand (2000), Raz et al. (2003), Shou & Yeo (2000), Steyn (2000a, 2002), Stratton (2009), Trietsch (2005), and Watson et al. (2007). Consultants embraced the methodology, and new project planning software tools followed. We survey such tools in Section 4.7.

CCPM gained traction in business schools. Pedagogically, it is praised for motivating critical thinking about the potential ills of traditional project scheduling and planning methods. Other advantages include bringing student attention to overlooked behavior issues, resource contentions, and multiple project environments. Since CCPM is about project planning and execution, it complements the broad range of topics that occupy a project management class (i.e, the strategic value of selecting the right projects, project budgeting, etc.).
If one believes in the merits of CCPM and wants to introduce it to undergraduate and/or graduate students, the first problem is selecting supporting materials. While some Operations Management textbooks now acknowledge CCPM in footnotes and sidebars (see, for example, Jacobs et al. 2009, p. 696) and some texts are dedicated entirely to CCPM (e.g., Newbold 1998; Leach 2005), we are aware of no textbook that systematically presents CCPM with examples, exercises, case studies and scientific references the way such resources exist for teaching traditional project management methods. That said, we find the resources summarized in Table 1 useful for pedagogical purposes.

Table 1: Resources for teaching critical chain project management

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
<th>Approx. Time</th>
</tr>
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<tbody>
<tr>
<td>Elton &amp; Roe (1998)</td>
<td>“Light” overview</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Newbold (1998, ch 8)</td>
<td>Numerical example of CCPM</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Budd &amp; Cerveny (2010)</td>
<td>Technical overview</td>
<td>90 minutes</td>
</tr>
<tr>
<td>Multitasking game</td>
<td>In-class game with debriefing</td>
<td>120 minutes</td>
</tr>
<tr>
<td>Goldratt (1997)</td>
<td>Business novel; in-depth motivation of CCPM</td>
<td>10 to 15 hours</td>
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One can combine these resources in various ways depending on course needs and available time. For example, in a core introductory operations class we have simply assigned Elton and Roe (1998) and offered extra credit to students who read and discuss Goldratt (1997). At the other extreme, a 3-credit project management class, we have required Goldratt (1997), Newbold (1998, chapter 8), run the Multitasking Game in class, shown Jacob’s (1998) video and required some of the exercises given in Section 4.

Despite how one combines any materials to present CCPM, one purpose of this paper is to address the mixed academic opinion about critical chain scheduling and buffer management. For instance, one concern is that the notion of a critical chain is not new, attributable to Wiest’s (1964) critical sequence (Herroelen and Leus 2001, p. 563) and a project buffer to O’Brien (1965) (Trietsch 2005, p. 31). Others feel some aspects of CCPM are simply not empirically justified, or worse, contradict well-accepted scheduling research (Herroelen and Leus 2001, Herroelen et al. 2002, Raz et al. 2003, Trietsch 2005). We summarize these issues and suggest appropriate classroom approaches to addressing them.

In addition to scholarly criticism of CCPM, there is a divide between traditional PERT/CPM methods and CCPM. Some feel CCPM does not properly complement currently-accepted project management practices, and in so doing, poses an unnecessary methodological choice between
CCPM and mainstream practices (Raz et al. 2003). “There is a variety of such methods some of which are mutually incompatible and attempting to describe them all is likely to cause confusion” (Nokes et al. 2003; see p. 26 for a comparison of nine differences). And it is our experience that students ask, “Why do you teach PERT when we learn so much from Critical Chain?” We report how we come to terms with this potential divide in our classes. For example, in Sec. 4.3 is an activity that we use to encourage students to puzzle over the differences between a PERT and CCPM schedule.

The purpose of this paper then, in summary, is to give teachers insights about adopting CCPM in a balanced fashion given that much of what has been written about the method has not been peer reviewed. It is intended for professors who are not necessarily experts in the literature of project management or scheduling theory, but are often asked to guide students in a unit on project management.

We assume that the reader has read Goldratt (1997) or is at least mildly familiar with CCPM. If not, alternatives include the brief chapter-by-chapter summary in Woeppel (2005), Budd and Cerveny’s (2010) overview, and the examples in Newbold (1998), especially Chapter 8. One of the authors uses these ideas in a stand-alone project management course; the other uses the ideas in MBA and undergraduate introductory operations management where at least 3 sessions can be devoted to the topic.

The paper proceeds as follows. First, in Section 2, we define CCPM, identify the ills of traditional project management that motivated it, survey related academic literature to understand if these are real concerns, and suggest strategies for sharing this information with students. In Section 3, we ask if CCPM works, survey the growing number of trade articles that say it does, and ask why there is little peer-reviewed literature to the same effect. In Section 4, we momentarily accept CCPM and develop a sequence of simple numerical examples that are intended to motivate critical student thinking about the CCPM methodology. Two are designed to practice resource-constrained project scheduling. The third requires students to reformulate a classic PERT/CPM problem as a CCPM schedule to highlight differences in the methodologies. The fourth is a simple example where resources are constrained across multiple projects. The last two critical-thinking exercises involve multitasking and buffer pooling. We conclude with our thoughts on CCPM in the classroom.
2. INVESTIGATING CCPM's MOTIVATIONS AND PERFORMANCE

Since CCPM is motivated by traditional project management’s supposed shortcomings, it is worth asking if scientific evidence in peer-reviewed journals (a) justifies these motivations and (b) agrees with CCPM’s prescribed solutions.

Before answering (a), it is useful to define the reasons behind CCPM more precisely. Because we recommend introducing students to CCPM through Goldratt (1997), our notion of CCPM is rooted in its use there, but we acknowledge that subtle variants can be found in Newbold (1998, Sec 1), Nokes et al. (2003), Leach (2005, Sec. 1.2), and Walker (2010) and others. Hence, we define the motivating factors and their prescribed solutions in Table 2.

<table>
<thead>
<tr>
<th>Traditional Project Mgmt</th>
<th>Proposed CCPM Solution</th>
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<tbody>
<tr>
<td>Safety time is imbedded in individual tasks</td>
<td>Reduce task time estimates; pool safety time in project and feeding buffers; eliminate accountability of intermediate milestones and change the culture around activity time estimation.</td>
</tr>
<tr>
<td>Parkinson's Law causes delays</td>
<td>Move safety time from individual tasks to project and feeding buffers.</td>
</tr>
<tr>
<td>Parallel activities are underappreciated</td>
<td>Insert feeding buffers where noncritical sequences join critical chain.</td>
</tr>
<tr>
<td>There is an early vs. late start dilemma</td>
<td>Let feeding buffers dictate noncritical activities’ start times.</td>
</tr>
<tr>
<td>Resource constraints occur across multiple projects</td>
<td>Recognize the resource(s) that is the critical chain</td>
</tr>
<tr>
<td>Multitasking happens</td>
<td>Avoid multitasking</td>
</tr>
<tr>
<td>Managers focus on cost</td>
<td>Focus on time</td>
</tr>
<tr>
<td>Projects finish late</td>
<td>All of the above</td>
</tr>
</tbody>
</table>

Realization Technologies expresses the proposed CCPM solution in different words. According to Gupta (2008, 2010) and Jensen (2010), a critical chain schedule is one that (a) limits the number of simultaneous projects (and hence multitasking) with staggered starts, (b) creates aggressive project plans with global buffers, and (c) avoids precise schedules and instead gives highest priority to tasks that consume the most buffer. Notice that (a), (b) and (c) are a subset of the right column, Table 2.

Let us now consider if project management scholars agree with the elements of Table 2, in order.

Safety Time Is Imbedded in Individual Tasks. There is evidence of inflated task time estimates in practice. One example is weather-related padding used in construction (e.g., see Clough and
Sears 1991). And there is evidence that pooling safety time is effective. For instance, Yeo and Ning (2006) present survey data and a model that suggest that pooled safety buffers are appropriate in construction equipment procurement supply chains.

But in practice is it always the case that we should shift safety margins from task owners to pooled buffers? First, let’s be clear what this means in CCPM.

Goldratt (1997) proposed a method sometimes called the 50% rule where original task time estimates and thus the critical chain’s duration are cut in half. Half of that savings is allocated to an end-of-project buffer and the net result is a planned project duration of 25% less time than the sum of original estimates. Feeding buffers are inserted where non-critical sequences join the critical chain using a similar procedure.

These methods drew some criticism. For example, Raz et al. (2003) argue that any benefits of pooled buffers have yet to be empirically justified and that, “Imposing shortened duration estimates on task owners will reduce their commitment to the estimates. In addition, the knowledge that their estimates will be reduced is likely to encourage task owners to add larger margins so they still have the safety margin they prefer after the correction” (Raz et al., p. 27). Others have argued this is not the case, that CCPM motivates a common goal. One illustration is the CCPM control of ITT’s Night Vision project (Cook 1998, Sec. 2.2; Jacobs 1998). Raz et al. also worry that since each added buffer is a new item on a Gantt chart, this may result in more clutter, potential confusion, and possibly more unscheduled communication to coordinate the project team (Raz et al., pp. 29-30).

Others support the notion of pooled buffers. In fact, in the project management literature, the idea of a feeding buffer can be traced back to the 1980s (see Trietsch 2005, p. 32, for references). That said, there is debate about their sizing rules. For example, Hoel and Taylor (1999, pp. 45-46) suggest buffer size alternatives that give particular probabilities of on-time project deliveries. Others have said, “The ex ante realistic 50% task duration estimate may well be based on loose ground. … In many cases, the result might be an unnecessarily large amount of protection, which could lead to uncompetitive proposals and the loss of business opportunities” (Herroelen and Leus 2001, pp. 562-564). Specifically, one numerical experiment showed that the root-square-error method for buffer size estimation is a more accurate approach (Herroelen and Leus 2001).
Having the most accurate buffer size and corresponding estimated completion date is of particular importance when projects must be won through bids which are evaluated, at least partially, based on the delivery date of the project. Indeed, almost every project selection method uses time in evaluating projects. For example, capital budgeting techniques use an interest rate to trade off time and money (Eschenbach and Cohen 2006) and the payback period is itself a time-based metric. Even methods that do not mandate explicit use of time estimates, such as cost/benefit analysis and scoring models, can readily account for time in their analysis. Also, when estimates are used for bidding purposes, best-value bids are not taken purely on cost but several factors including delivery dates (Gransberg and Ellicott 1997; Kashiwagi and Byfield 2002). Hence, though an arbitrary 25% reduction in project duration may be impressive when the project manager and owner are the same, it may prove uncompetitive when projects must be won through bidding.

We know of several CCPM practitioners who don’t use the 50% rule yet articulate the value of buffers. For example, Newbold (2009) says,

[I]f you cut people’s task durations by 50% as a standard approach, you run a huge risk of destroying the credibility of your schedules. More generally, poor schedule building or buffer sizing in any form can make buffering ineffective. However, the validity of the buffering concept is easily demonstrated and should be considered independently of the mechanism used to size buffers.

The message we emphasize with students is what other leading project management consultants told us: that more important than the question of the size of the buffer is the underlying cause of inflated task times, namely, that workers are held accountable for intermediate milestones even though such deadlines are irrelevant when projects finish on time. Thus to get more accurate time estimates, two things are done: (a) the highest levels of management acknowledge in writing that individuals will not be held accountable for individual task deadlines, and then (b) particular language is used to coach employees to give good time estimates, such as, “what is your actual touch time on this activity?”

Step (a) is a rather dramatic cultural change for some firms. A recent case study of its effectiveness is the Japanese Ministry of Land, Infrastructure, Transport and Tourism which created a culture of accurate time estimates and pooled safety time in public works projects. With the aid of several influential people including Kishira (2009a), and the related “Safety Bug”
animated video series (Kishira 2009c), this so-called “Win-Win-Win Public Work Reform” has realized impressive lead-time reductions. Kishira’s work highlights the two foregoing steps (a) and (b) that are necessary for buffering to work. As an aside, we find Kishira’s (2009c) videos liven any classroom discussion.

**Parkinson’s Law Reigns.** Parkinson (1955) said, “Work expands so as to fill the time available for its completion,” a phenomenon that was tested empirically (Moss 1978) and later confirmed in projects (Schonberger 1981, Gutierrez and Kouvelis 1991). Advocates of CCPM introduced the metaphor *student syndrome* (e.g., see Goldratt 1997, Budd and Cerveny 2010) to demonstrate their belief that Parkinson’s Law leads to further delays.

Parkinson’s Law has been well documented empirically. For example, Hill et al. (2000) found that 32% of 500 software development activities overran time estimates under traditional project control methods. This suggests that two-thirds of the activities were buffered to complete early or on time, an unlikely target at best. However, when one considers that Parkinson’s Law resulted in time expanding to move average time closer to the buffered time, it is not surprising that only 68% of activities would be covered by a buffer chosen to achieve 90-99% on-time completion.

Herroelen and Leus (2001) suggest Parkinson’s Law is not necessarily bad, “since you cannot have the workforce under stress all the time” (p. 562). This raises the question of whether the student syndrome is the result of procrastination as the name implies. While there is a deep psychology literature that suggests a complex array of factors contribute to procrastination (e.g., see Steel 2007), Bender et al. (2008) say, “The advantages of procrastination are well documented: the closer to a deadline a task is executed, the less processing time the task appears to require. Hence, it is common for a person to delay executing some onerous job in order to spend as little time as possible working on it” (p. 95).

Procrastination is not necessarily the result of laziness, but rather the case of workers with multiple deadlines on multiple projects. The expedient action (from the worker’s point of view) is to optimize personal workflow by selecting tasks in order of individual deadlines. The message we emphasize to students is that given a due-date, it is rational (and likely efficient) to finish a job near the due-date, and in reality, people do not estimate the time required to complete a task but rather the time by which the task will be completed. That is, they quote due dates, not activity durations. Thinking of the estimate of an activity’s duration as a due date, it no longer implies
that someone is lazy or wasting time if they complete the activity near the due date. Rather, they are likely being efficient.

Regarding Parkinson’s Law, it is worth noting that most people will not be assigned to just one task, but multiple tasks, perhaps on multiple projects. If they schedule their time efficiently, they will complete most of their activities on time but not early. Again, this is not because workers are lazy or wasteful, but due to the structure of an optimal schedule for minimizing tardiness-based objectives. Whether or not CCPM reduces or outright avoids the impact of Parkinson’s Law is still an open research question.

**The Importance of Parallel Activities Is Underappreciated.** One of CCPM’s motivations is that delays in noncritical activities can lead to unrecoverable project delays. On one hand, this assertion is well-founded. For example, Schonberger (1981) showed that projects with variable activity times will always exceed the time of the deterministic critical path with the greater the variability or number of parallel paths, the greater the delay.

The CCPM response is the insertion of feeding buffers where noncritical sequences join the critical chain. However, the more parallel paths in a project, the greater the chance that noncritical chains will turn critical and thus feeding buffers will have been misplaced (Raz et al. 2003, p. 28). While some CCPM practitioners argue for careful daily monitoring of buffer consumption (see, for example, Gupta 2008 and 2010), our example 4.3b (below) is designed to bring student attention to this point; note how all feeding buffers cannot be assigned a time duration prescribed by the 50% rule.

**There Is an Early vs. Late Start Dilemma.** If noncritical activities follow earliest or latest start times, it is said the project leader will lose focus, resulting in costly delays (e.g., see Goldratt, pp. 70-71). The remedy according to CCPM is that feeding buffers dictate the start of noncritical sequences.

One criticism of the approach, according to Herroelen and Leus (2001, pp. 565-566) is that “Pushing activities backward in time in order to insert a feeding buffer may, and mostly will, create resource conflicts. How these conflicts are to be resolved is not described in detail. A possible way for resolving the conflict may be to push the chain of activities feeding a feeding buffer backwards in time until a feasible schedule is obtained again.”
Example 4.3 (below) is designed to highlight other feeding buffer insertion complications.

**Resource Constraints Occur Across Multiple Projects.** While not new, resource leveling through the critical chain—that is, keeping the amount of resources tied up in a project as consistent as possible over the project’s lifetime—is an important element of CCPM. However, Raz et al. (2003) question the applicability of a critical chain project solution given that the binding resource across different projects could alternate at different points of time. We invite students to explore a simpler case of constraints across projects using example 4.4 below.

**Multitasking Happens.** It is our experience teaching CCPM to undergraduates that an important lesson is the loss of focus and productivity and increase in lead times induced by what CCPM practitioners call “multi-tasking” (Goldratt 1997, pp. 125-127) or “multitasking” (Budd and Cerveny 2010, p. 58). Undergraduates often remark how they identified and eliminated multitasking in their personal lives as a result of the reading. By multitasking, we mean the assignment of one resource to multiple tasks or projects, potentially leading to task completion delays, and thus possible project delays. However, due to the more familiar meaning of multitasking in North American culture—“the human attempt to do simultaneously as many things as possible, as quickly as possible, preferably marshalling the power of as many technologies as possible” (Rosen 2008)—students sometimes miss this point. To clarify this difference we recommend reviewing Goldratt’s (1997) figure on p. 126 to explain the project definition.

This notion can be further demonstrated by having students play the Multitasking Game in class. Students roll dice to randomly simulate the progress made on three separate identical projects each week. First, students simulate project execution with multitasking when each project is given equal priority and workers alternate between projects. Second, students simulate project execution without multitasking when projects are prioritized and workers concentrate on the highest priority project. One of the authors has had success using this game to demonstrate multitasking in the classroom and the game has also seen successful use in project management courses at Case Western Reserve University (Vairaktarakis, 2010) and Ohio State University (Hall, 2010). A simple on-line multitasking activity is also available to demonstrate the concept for projects ([http://billiondollarsolution.com/multitasking.html](http://billiondollarsolution.com/multitasking.html)).
To contrast the cultural definition we invite students to listen to Hamilton (2008) and the humorous Sharp (2008) as well as playing the online game “Multitask” (kongregate.com/games/IcyLime/multitask).

With regard to the cultural meaning of multitasking, the research firm Basex estimated that interruptions and information overload of white-collar/knowledge-based workers take a $650-billion toll on lost productivity and innovation throughout the US economy (Lohr 2008). However, assuming that interruptions are kept to a minimum, there is evidence that the project management definition of multitasking is beneficial when carefully applied to projects. For example, McCollum and Sherman (1991) found that assigning R&D employees to up to three simultaneous projects improved return on investment. Trietsch (2005; p. 32) concurs that multitasking is unavoidable and sometimes desirable in practice. And according to Demeulemeester and Herroelen (1996) and Herroelen and Leus (2001), multitasking can lead to activity preemption, stopping work on a lower priority activity to work on a higher priority activity that has just become available, which has been shown to shorten project durations.

Indeed, it is well known that multitasking increases scheduling flexibility. In the end, there is a difference between efficient assignment of resources to a project and efficient use of resources within an organization. Also, there is a difference between departmental and individual commitments to complete a task. Departments obviously must accept many requests for work, so requiring that no one in a department be assigned to more than one task at a time would make the department manager’s scheduling task impossible, even if it works for the project manager. In the end, properly used, multitasking should improve project success; abuse of multitasking can prove detrimental to a project’s success.

**Managers Focus on Cost.** Evidence suggests that a “cost minimization mentality” is less profitable. For example, Port et al. (1990) cite a McKinsey & Co. estimate that firms lose one third of their profits when they accept six-month delays to stay within product development budgets; spending 50% more than budgeted to meet a release date attenuates total profits only 4%.

Of course, this is dependent on the definition of “on time.” If buffers and due dates change then the meaning of “on time” also changes. If PERT/CPM project management is about completing projects on time with minimum cost and if the notion of on time is erroneous, this can be a failed
approach. However, NPV project management is geared toward maximizing project NPV (Herroelen et al. 1997) and can clearly identify what on time should mean. Hence, though practicing project managers may exhibit a tendency to focus too much on cost and not enough on time, this is not a deficiency in project management theory itself which seeks to balance the objectives of time and cost. Indeed, always striving to complete earlier with no regard to budgets can be just as detrimental to project success as sacrificing time for cost. In particular, when the project manager’s company is acting as a contractor and does not own the completed project, the benefits of earlier project completion are significantly less. Further, these benefits may well be clearly quantifiable based on the contract with the project owner.

Overall, it is a valid point that project success is not about meeting a target project budget or even a target project due-date. If the goal of a project is to generate profit then the ultimate profitability of the project could be the determinant of the project’s success. If profitability can be improved by spending more money to finish sooner or by spending less money to finish later, then so be it.

Finally, we suspect that the focus on time, not cost, is the spirit of W. Edwards Deming’s fourth point: “end the practice of awarding business on price alone” (Walton 1986).

Projects Finish Late. The characters in Goldratt (1997, p. 25) joke that, “Everybody knows projects don’t finish on time or on budget, and even if they do, it means they had to compromise on content.” Frequently-cited empirical evidence of this statement is the Standish Group’s long-term study of thousands of IT projects around the globe. The average delay, cost overrun and percent canceled prior to completion are noteworthy (for details, see Woeppel 2005, p. 105, and Klastorin and Mitchell 2005, p. 23). Leach (2005, p. 6) surveys other project management planning anecdotes in other industries. The question, however, is this: is CCPM the antidote to late projects? We address this in more detail in the next section.
3. DOES CCPM DELIVER?

We are unaware of any scientific study that assesses performance metrics of a sample of projects controlled with CCPM vs. traditional methods. That said, the number of case studies of successful project execution due to CCPM is burgeoning. These include private, public and government agencies and the documented improvements include substantial time savings, profitability, customer satisfaction, and worker enthusiasm. Table 3 gives a sample from Barber et al. (1999), Cabanis-Brewin (1999, p. 50), Cook (1998), Fenbert and Fleener (2002), Goldratt (2009), Gupta (2003), Honeywell Corp. (1998), Hunt (2004), Jensen (2010), Kishira (2009b), Leach (1999, p. 40), Leach (2005, pp. 19-21), Parr (2000a), Rand (2000), Simpson and Lynch (1999), Srinivasan et al. (2004), Srinivasan et al. (2007), Umble and Umble (2000, p. 28), Woeppel (2005, pp. 110-111), and the testimonials from Realization Technologies, Inc. (see Realization.com) and Avraham Goldratt Institute (AGI; see Goldratt.com).

Table 3: Organizations that documented project management improvements due to CCPM.

| A13 Motorway Construction Project (United Kingdom) | Japanese Ministry of Labor, Infrastructure, Transport & Tourism (MILT) |
| Abb Group | LeTourneau, Inc. |
| Action Park Multiforma Grupo | Lockheed Martin |
| Airgo Networks (now QualComm) | Lord Corp. |
| Alcan Alesia Technologies | LSI Corp. |
| Alna Software | Lucent Technologies (now Alcatel-Lucent) |
| Amdocs | Marketing Architects, Inc. |
| Balfour Beatty Civil Engineering Ltd. | Medtronic |
| BHP Billiton | Northern Digital, Inc. |
| Boeing, Space & Intelligence Systems, Manufacturing R & D and Satellite Manufacturing, and F22 Raptor | Oregon Freeze Dry, Inc. |
| Bosch Security Systems | Pratt & Whitney |
| Central Nuclear Almaraz Trillo | Proctor & Gamble Pharmaceuticals |
| DaimlerChrysler, Automotive Product Development | Rapid Solutions Group |
| Delta Airlines | Skye Group |
| Dr. Reddy's Laboratories | Tata Steel |
| Duke Energy | TECNOBIT |
| e2v Semiconductors | Thru-Put Technologies |
| Ericom | ThyssenKrupp Krause, Ltd. |
| Erikson Air-crane | US Army: Corpus Christi Army Depot |
| French Air Force | US Air Force: Operational Test & Evaluation Center, Warner Robins Air Logistics Center (ALC), Ogden ALC, Oklahoma City ALC |
| Genencor | US Marine Corps: Logistics Bases in Albany, GA & Barstow, CA |
| Habitat for Humanity | US Navy: Cherry Point, NC Aviation Depot, Pearl Harbor Shipyard |
| Hamilton Beach/Proctor-Silex, Inc. | Valley Cabinet Works |
| Harris Semiconductor | Von Ardenne |
| Hewlett-Packard, Digital Camera Group | Votorantim |
| Honeywell Defense Avionics Systems |  |
Though some of the above references were not peer-reviewed or were contributed by authors with an economic interest in the CCPM methodology, we suspect the actual list of successes is longer. For example, by 1999 it was said that CCPM was proved in over 1000 case studies (Cabanis-Brewin 1999), and we know of several consultants bound by non-disclosure agreements who talk off-the-record about impressive achievements due to CCPM in well-known corporations and government agencies.

In the interest of a balanced appraisal of CCPM, one might ask if reported gains are attributable to the Hawthorne Effect (changes in behavior due to being studied) or the novelty of new management methodologies. The literature is inconclusive, though some argue informally that the Hawthorne Effect is unlikely in project organizations (e.g., see Cabanis-Brewin 1999, pp. 50-51). Two related concerns are noteworthy: sustainment—the endurance of CCPM control methods after the original “CCPM champion” has been promoted or otherwise moved on—and outright project failures. We know several cases in industry and the US military where these have been problematic but not reported publically.

Another pair of related issues is self-selection and self-reporting of users of CCPM. With regard to self-selection it may be the case that only those users for whom non-CCPM tools are failing who would try CCPM. Hence, the case-by-case comparison of CCPM and non-CCPM practices is biased against non-CCPM tools. With regard to self-reporting, it seems likely that companies are more likely to promote and publicize successes than project failure stories. Hence, a number of failed attempts at using CCPM are unlikely to go reported. Indeed, our conversations with consultants reveal such events are likely to be shielded by non-disclosure agreements.

Finally, scholars have written about situations where CCPM is theoretically not the ideal control method. For example, Herroelen and Leus (2001) suggest buffer sizing improvements in single and multiple-project environments, and similarly, Cohen et al. (2004) suggest alternatives to CCPM control that reduce makespans of multiple projects.
4. NUMERICAL EXAMPLES AND COUNTEREXAMPLES

We now present a sequence of numerical examples to motivate critical thinking and provide supplemental practice in critical chain scheduling. Detailed discussion of the solutions is available as a teaching note in the appendix.

4.1 Simple CCPM Formulation: The Project of Jack and Jill

The first example is a simple resource-constrained project that we find useful for less technical undergraduate students from various business disciplines. Some will find this example unnecessary; it was conceived for the student who does not immediately understand the meaning of person “X” in Goldratt (1997), the figure on p. 218. Consider a project with the activity precedence relationships and time estimates given in the following table.

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<thead>
<tr>
<th>Activity</th>
<th>Immediate Predecessor</th>
<th>Estimated Time (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>--</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>B, C</td>
<td>10</td>
</tr>
</tbody>
</table>

Two workers are available. Due to her skill set, Jill is responsible for activities A and D. Similarly, only Jack can do activities B and C.

(a) Assuming that the time estimates are perfectly accurate, what is the planned project duration? Explain. (Use the time estimates as is; do not insert project or feeding buffers.)

(b) Which activities are critical? Explain.

(c) Assume Jack and Jill can be cross-trained to do any activity, but will not share activities. Can the activities be reassigned to Jack and Jill such that the project is completed in less time? If so, indicate the new assignment and project duration.

(d) Consider the following staffing assignment: Jill does activities A and B, Jack does activities C and D. Assume that the times in the foregoing table are estimates padded with safety time. Use critical chain scheduling ideas to reformulate the project schedule using project and feeding buffers. Include a diagram similar to that on Goldratt’s page 218.
4.2 Resource Constraints within a Project: The Project of Person “X”

This example was also developed to aid in debriefing Goldratt (1997), specifically the conceptual project diagrams on pages 214 and 218. The following example asks students to develop such a diagram from a numerical example. (We do not tell students that it results in an identical figure to that on p. 218.) Consider the following project activity list.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Immediate Predecessors</th>
<th>Estimated Activity Time (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>--</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>--</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>C</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>F</td>
<td>E</td>
<td>5</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>H</td>
<td>G</td>
<td>8</td>
</tr>
<tr>
<td>I</td>
<td>B, D, H, K, M</td>
<td>4</td>
</tr>
<tr>
<td>J</td>
<td>--</td>
<td>3</td>
</tr>
<tr>
<td>K</td>
<td>J</td>
<td>2</td>
</tr>
<tr>
<td>L</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>L</td>
<td>7</td>
</tr>
</tbody>
</table>

One person (called person “X”) is the only employee with the skills needed to accomplish activities B, D, F, K, M. Each remaining activity (A, C, E, G, H, I, J, L) has a unique person assigned to the task and can therefore be completed independently of other activities. Develop a critical chain project schedule. Include a figure similar to that on page 218 and indicate the duration of activities and buffers.

4.3 PERT vs. CCPM: The Project of Reliable Construction Company

The purpose of this next example is to convert a well-known PERT problem into a critical chain plan using CCPM methods, forcing students to consider methodological differences between PERT and CCPM. It also presents three situations not formally addressed in most CCPM references: (i) when critical activities precede noncritical activities, (ii) when there is task time distribution information and (iii) when the 50% rule for feeding buffer allocation is infeasible. Again, because we introduce the method from Goldratt (1997), the problem is framed about that reference, though it need not be.
Consider the project of Reliable Construction Co. (Hillier and Lieberman 2001) with the precedence relationships (Table 10.1, p. 469) and optimistic ($o$), most likely ($m$), and pessimistic ($p$) time estimates (Table 10.4, p. 488) and expected critical activities A-B-C-E-F-J-L-N that yield the expected project duration 44 weeks.

(a) In Goldratt (1997, p. 156), the characters ultimately decide that “time allotted for each step will only be cut by one-half. On the other end, the project buffer will not be equal to what they trimmed. It will be set to only half of it.” We call this the 50% rule. Considering the spirit of the 50% rule, reformulate each time estimate and the duration of the project buffer. What is the revised planned project duration?

(b) Similarly, regarding noncritical activities, “For each feeding path they decide to cut the original time estimates of the steps in half and use half of the trimmed lead time as a ‘feeding buffer’” (Goldratt, p. 158). Use this information to sketch a figure similar to that at the bottom of page 158 for the project. In the figure, indicate the duration of each activity and buffer.

(c) The 50% rule is just one approach to achieve a more general philosophy of CCPM, namely, that activity times should not be padded but rather “aggressive but doable” with a collectively-shared buffers inserted in appropriate places (i.e., the project and feeding buffers). However when you considered a PERT problem, you were presented with three numbers: optimistic, most-likely, and pessimistic time estimates for each task. Describe how you used these three times to create an “aggressive but doable” estimate for each task and your reasoning for doing so. Explain.

4.4 Resource Constraints across Multiple Projects: The Company of Jack & Jill & Jane

The purpose of this problem is to give students practice with resource constraints across projects, an idea that is mentioned but not developed in the references in Table 1 (above).

The Company of J&J&J has two projects. One is the project of Jack & Jill (where Jill must perform A and D and Jack must perform B and C, as given in the table in section 4.1). The other is the project of Jack & Jane which is identical to the project of Jack & Jill but the activities are labeled E, F, G, and H where Jill must perform E and H. It is more expensive to delay the project of Jack & Jill. Find the schedule for these two projects.
4.5 Is Multitasking Always Bad?

Consider a project with the activity precedence relationships and time estimates given in the following table.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Immediate Predecessor</th>
<th>Estimated Time (weeks)</th>
<th>Qualified Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>--</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>3</td>
<td>Jack</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td>1</td>
<td>Jill</td>
</tr>
<tr>
<td>D</td>
<td>C</td>
<td>3</td>
<td>Jack</td>
</tr>
<tr>
<td>E</td>
<td>A</td>
<td>6</td>
<td>Jill</td>
</tr>
<tr>
<td>F</td>
<td>D, E</td>
<td>0</td>
<td>--</td>
</tr>
</tbody>
</table>

Activities A and F are dummy activities indicating project start and completion. Two workers are available. Due to her skill set, Jill is responsible for activities C and E. Similarly, only Jack can do activities B and D. Since Jack’s activities are ordered by the precedence relationships, there is no opportunity for Jack to multitask. However, Jill’s activities are not ordered by precedence constraints and therefore she may multitask, that is, work on both activities C and E at the same time. However, since multitasking is inefficient, assume that Jill’s total output is only 2/3 of what it would be if she dedicates her time to only one activity. In other words, any week that Jill multitasks activities C and E, that week will require 50% more time than originally budgeted (requiring 3 weeks of multitasking to complete one week of work on both activities simultaneously). Should Jill multitask? Why or why not? Explain.

4.6 Anecdotal Reasoning?

We use this example to clarify something that people read in Goldratt (1997).

CCPM supposes that task buffering is wasteful in organizations and that it is easy to eliminate vast amounts of time from a project. For example, in Goldratt (1997, pp. 183-184), the hero manages to get a coatings subcontractor to agree to “drop everything else and work on it” when a job arrives. The only apparent barriers for the subcontractor are a price increase and that he be given ten days’ notice (with updates) of the job’s arrival. Identify as many problems with this exchange that you can imagine. Explain.

4.7 CCPM Software; Other Computer Activities and Games
According to Vinson (2010), there are a number of project management software tools with critical chain capabilities, including Agile-CC by AdeptTracker, Aurora-CCPM by Stottler-Henke, BeingManagement2 by Being, cc-Pulse/cc-MPulse by Spherical Angle, CCPM+ by Advanced Projects, Concerto by Realization Technologies, Inc., Lynx by A-Dato, ProChain by ProChain Solutions, and PSNext by Sciforma. ProChain is available to professors at no charge (see prochain.com/services/university-program.html). Instructors of more advanced project management classes may wish to ask students to formulate examples 4.1 to 4.4 using such software.

In addition to the multitasking games mentioned earlier, other CCPM games worth considering include James Holt’s at www.wsu.edu/~engrmgmt/holt (see “TOC Project management Games” under EM530) as well as what is now being called “Tony Rizzo’s Bead Game” for resource-constrained project scheduling in a multi-project setting (see Roggenkamp et al. 2005).

5. CONCLUSION

We hope that this document gives instructors actionable ideas for their project management lesson plans and helps them decide what content, if any, regarding CCPM they will include in a syllabus. Our conclusion is that a unit on CCPM enriches a traditional project management course by exposing the potential pitfalls of standard scheduling methods. While some practitioners tell us that CCPM replaces such methods, from a pedagogical perspective we feel CCPM is a complement. It’s the comparing and contrasting of CCPM with established practices that motivates deep student thinking and learning.

Despite the lack of scientific, peer-reviewed evidence about the effectiveness of critical chain project control, we feel the method contributes unique enrichment to a student’s project management education. In the way Deming’s methods were about instilling cooperation in teams to work toward a common goal, the teachings of CCPM promote more selfless collaboration in project organizations. For example, the majority of the success stories surveyed in Table 3 include anecdotes of greater worker enthusiasm, enhanced sense of teamwork, and more joy in work. On this basis, it seems the cultural shift of eliminating individual milestone responsibilities and the resulting working together with aggressive time estimates and shared buffers has the potential to be one of the most important contributions and innovations due to the methodology.
Finally, CCPM was never intended to address certain aspects of project management that are thus intentionally absent from this review. These include the distinction between successful projects and successful project planning (for more, see Raz et al. 2003, p. 30), capital budgeting and the strategic importance of choosing the right projects, and budgeting individual projects properly. We also do not address how one teaches CCPM implementation nor how CCPM methods accommodate scope creep.

ACKNOWLEDGEMENTS

We wish to thank Eliyahu Goldratt for writings that have motivated three decades of intellectual activity. Thanks also go to Bahadir Inozu, Rob Newbold, Nick Hall, George Vairaktarakis and Bert De Reyck for useful discussions and feedback. We are grateful to Jeremy Schwartz and Ting Lo for advanced readings of the manuscript. The first author was supported in part by funding by the Baruch College Fund.

APPENDIX: Solutions to Examples 4.1 to 4.6

Example 4.1

(a) Jack requires \(12 + 4 = 16\) weeks to complete activities B and C. Therefore the project duration is \(6 + 12 + 4 + 10 = 32\) weeks.

(b) All activities are critical because the critical chain is either A-B-C-D or A-C-B-D.

(c) There are multiple correct answers. One possible solution is assign A and B to Jill; C and D to Jack. The project duration reduces from 32 to 28 weeks.

(d) The activity times for A, B, C, and D would be reduced to 3, 6, 2, and 5 weeks, respectively. The duration of the project buffer would be half the savings, namely, 7 weeks. The feeding buffer (FB) for noncritical activity C is one week. Activity C should begin at the end of the sixth week of the project as indicated below. Using Goldratt’s notation, this can be visualized as follows:
Example 4.2
After cutting time estimates in half, students who fail to observe the resource constraint will erroneously obtain a solution similar to that on page 214 with the critical path E-F-G-H-I and project duration 16.5 weeks (including the project buffer). Such a diagram follows. All units are weeks.

[Diagram of project network with activities and durations]

Noting that person X is responsible for activities B, D, F, K, M (or a total time of 13.5 weeks, 2.5 weeks longer than the 11-week critical path E-F-G-H-I), it is clear that there is a critical chain.

We could redraw the foregoing figure similar to that on page 218, as shown below. The critical chain is person X’s activities plus any activities that delay X from starting (the shortest of which is L, ½ week) and any activities that delay the project completion when X is done (activity I, 2 weeks). Thus, the planned project duration is now 24 weeks.

[Diagram of project network with critical chain highlighted]

Example 4.3
(a) If task owners obtain initial time estimates using the PERT three-estimate approach (given in Hillier and Lieberman 2001, p. 488), it is unclear how one applies CCPM’s 50% rule to these three estimates. We encourage discussing the effects of three possible interpretations:
a. **Interpretation**: Cut each of the three estimates $o$, $m$ and $p$ in half, or equivalently, cut the time estimate $\mu = (o+4m+p)/6$ by half. **Result**: The critical chain would be the sequence A-B-C-E-F-J-L-N with planned duration 22 weeks. The project buffer, if half of the critical chain’s time, is 11 weeks, and thus the planned project duration is 33 weeks.

b. **Interpretation**: Since CCPM encourages honest, unpadded time estimates, one might argue this is essentially captured by the most likely estimate $m$, thus $m$ is the most appropriate time estimate for each task. **Result**: The critical chain remains A-B-C-E-F-J-L-N of length 43 weeks, the project buffer would be 22.5 weeks, and the planned project duration 67.5 weeks.

c. **Interpretation**: If one were to apply a 50% rule to PERT, perhaps the only number that is inflated is the pessimistic value $p$. Therefore only $p$ should be divided in half and activity times are computed $(o+4m+p/2)/6$. **Result**: The critical chain remains A-B-C-E-F-J-L-N of length 38.25 weeks, the project buffer is 19.125 weeks, and the planned project duration is 57.375 weeks.

(b) The following solution is based on the first interpretation in part (a). In the following figure, the feeding buffer for the noncritical chain D-G-H-M should be 6 weeks but only 5 are available. Similarly, the feeding buffer for I should be 1.75 weeks but only 1 is available and the feeding buffer for K should be 1 week but only a half-week is available. All durations in the following figure are in weeks.

(c) See part (a). It’s generally not clear which is the correct interpretation of the 50% rule applied to the three PERT time estimates. That however is exactly the point. By being puzzling and open-ended, it challenges students to construct a deeper understanding of both PERT and CCPM methods.

A classical PERT formulation of the original problem reveals that activities on the expected critical path are the same as the critical chain above, and thus the expected project duration and
variance are 44 and 9 weeks, respectively. Contrast the CCPM formulation’s planned 36-week project duration with the PERT formulation’s implication that there is 99.6% chance that the actual project duration is greater than 36 weeks.

In general, one should be cautious when comparing a CCPM project duration with the length of a PERT expected critical path, since CCPM assumes a more hands-on approach. For insights comparing time/cost estimates on projects with hands-on and hands-off managerial approaches, we recommend Jørgensen and Wallace (2000).

**Example 4.4**

Step 1: Prioritize projects. According to CCPM, the project of Jack & Jill receives priority due to the delay cost.

Step 2: Find independent schedules for the two projects. For the project of Jack & Jill the critical path is A-B-C-D (it is also optimal to transpose B and C) taking time 3+6+2+5=16 weeks and receiving a buffer of 8 weeks for a completion date of 24 weeks. For the project of Jack & Jane the schedule is the same using the critical path E-F-G-H.

Step 3: Resolve resource conflicts in favor of the higher priority project. The bottleneck resource is Jack since he is needed on both projects from time 3 through time 11. We resolve this by giving priority to the project of Jack & Jill. So, starting at time 3 Jack will execute the sequence of critical activities B-C-F-G. This results in no change in the project of Jack & Jill. But, the project of Jack & Jane is delayed. Jack will not start activity F until he finishes activity C at time 11. So, using the late start schedule for project Jack & Jane, Jane will now start activity E at time 8 so that it finishes at time 11. This means the entire schedule for project Jack & Jane will be delayed 8 weeks with a completion date of 32 weeks, as shown in the following Gantt chart (grey shading refers to Jack and Jane’s project.)

| Resource | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Jack     |     |     |     |     |     | A   |     |     |     |     |     |     |     | B   |     |     |     |     |     |     |     |     |     |     |     |     |   (6 wks)  |
|          |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |   (2 wks)  |
| Jill     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | D   |     |     |     |     |     |     |     |     |     |     |   (6 wks)  |
|          |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |   (2 wks)  |
| Jane     |     |     |     |     |     |     |     |     |     |     |     | E   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |   (3 wks)  |
|          |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |   (5 wks)  |
Using CCPM, this results in a critical sequence of activities across two projects of A-B-C-F-G-H, as shown below.

![Diagram](image)

Comments:

1. We do not sequence a feeding buffer between E and F since these activities lie on the project’s critical chain, though this point is not clear from the book.

2. This CCPM schedule has several attractive properties. Including the project buffer, the project of Jack & Jill has a completion date of 24 weeks. No other schedule can provide an earlier completion date. The project Jack & Jane cannot have a completion date less than 32 weeks. Hence, the CCPM schedule provides the best possibility both for the high priority project and for the low priority project.

3. Suppose we allow Jack to multitask and work on both projects at the same time. Then, even if multitasking is inefficient, it could be possible to complete both projects later than 24 weeks but before 32 weeks. When might this be a good idea? If we assume a very strict priority hierarchy, delaying one project 8 weeks is better than delaying the other project just one week. But what if the cost of delaying the two projects was about equal beyond a certain date?

4. Jack moves between the two projects. In particular Jack needs to be updated about the progress on activities A and E so that he is ready to start B and F once they are available. Whenever such a resource switch occurs along the critical chain, this should be handled with a resource buffer which is not a time buffer but an early warning system for the resource to not be late.

**Example 4.5**

Despite the inefficiency of multitasking, the schedule that completes the project as early as possible requires it. To see why, consider the following schedule which completes the project as early as possible without multitasking:
Without multitasking, we must sequence activities C and E, resulting in a 10–week minimum project duration since C has a predecessor and successor that require 3 weeks. Now, consider the revised schedule if multitasking is used:

The project is now completed in 9 weeks. Though Jill is less efficient (she requires 8 weeks to do 7 weeks’ work), the project finishes sooner because her 8 days of work start immediately whereas the 7 days of work were delayed 3 days for activity B. Hence, we conclude that though multitasking is inefficient for individuals it need not be inefficient for projects and organizations as a whole.

**Example 4.6**

There are three problems with this exchange. First, the subcontractor never promises how long it will take to complete the job, and therefore, they do not actually know what they are getting for the extra money. Second, since the commitment is not to finish the job at a certain time but to start it after arrival, the only way to verify that the promise is being kept would be to have someone in the shop monitor progress during the completion of the job. Third, suppose the same subcontractor has another client making use of CCPM. What if the two jobs which are to be given top priority from the two different customers arrived at the same time? The subcontractor would renege on at least one commitment. Similar problems were encountered and solved during the implementation of CCPM in the Warner Robins Air Logistics Center as detailed in Srinivasan et al. (2007).
The shortsightedness of these examples also extends to cutting time on jobs performed within an organization. Consider the example of the 7 weeks required to purchase a connector (Goldratt, p. 48). Suppose the actual work to place the order requires less than 15 minutes; if the supplier is out of stock someone could purchase the connector at a local electrical supply store in at most a few hours. Goldratt, however, implies that using CCPM would save such projects weeks of delay by reducing the length of the connector acquisition time to at most one day. In rebuttal, we propose three alternative scenarios:

1. The department head explains that the connector request must be handled through standard procedures so that no favoritism is shown.

2. The department head originally agrees. But, the next day when ten other project managers demand equal treatment having heard about the promise, he phones to renege on the promise.

3. The department head, having been trained in operations management techniques, dedicates a single staff member to process work requests which take 15 minutes or less to complete. This way, no such job will wait more than 24 hours before being processed. Similarly, the department head has guaranteed the quality and responsiveness of suppliers so that extended delays from stock outs are not an issue. All ten project managers throughout the company will experience significantly improved service while never employing CCPM.

The last scenario highlights that the issue is not a buffering issue. The large buffers are appropriate given how the department is being operated. But, rather than addressing underlying scheduling issues within the department, the story addresses the buffering issue for one project. This leaves the disease but treats the symptom; CCPM gets credit for treating a symptom while other projects within the organization suffer from the disease. Also, an analogy can be made with just-in-time (JIT) or lean philosophies where the inflated buffer is thought to hide inefficiencies within the organization. Hence, an application of JIT or lean management should fix the problem with no need for CCPM techniques.
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