

Putting Quality in Project Risk Management: Understanding Variation

By

Lawrence P. Leach

Summary

Project managers should use the tools of quality management to improve prediction and control of project schedule and cost. This paper hypothesizes that management actions arising from the present PMBOK [PMI, 1994] cause poor performance of the project management system. Lack of understanding common cause and special cause variation underlies the problem, leading to management mistakes that degrade performance of the project system. Critical Chain Project Management (CCPM) provides one approach to improve on present practice through:

1. Keeping the critical chain fixed throughout a project, and
2. Sizing buffers and setting action criteria at levels that should only cause management response to special causes of variation.

Significant opportunity exists for future improvement to the science of project performance through applying control charts. In the mean time, project risk management must differentiate between the two types of causes of variation.

The Problem

Dr. W. Edwards Deming, the man credited with the post-war industrial revolution in Japan, stated [Deming, 1982], "It would be a mistake to export American management to a friendly country." His reasons for this harsh statement are grounded in the many mistakes management makes in attempting to control the system of production. Two of these mistakes may be institutionalized in the PMBOK, and must change if project performance is to improve substantially.

In his later years, Deming put increasing emphasis on the necessity of management to use a "system of profound knowledge" [Deming, 1993] He defines the system of profound knowledge to include, 1) appreciation for a system, 2) understanding of variation, 3) psychology, and 4) a theory of knowledge. His theory of knowledge uses the scientific method.

Major breakthroughs were made early in this century leading to improvements in the quality of life for billions of people around the world. The later stages of the industrial revolution used scientific management to improve production processes. Dr. Walter A. Shewhart was an acknowledged leader in this field, and mentor to Dr. Deming. Deming's forward to Dr. Shewhart's book on Statistical Method [Shewhart, 1986] notes, "some of the greatest contributions from control charts lie in areas that are only partially explored so far, such as application to supervision, management, and systems of measurement..." Shewhart notes that the use of process control provides a "means of directing action toward the process," so that management can say, "If you do so and so, then such and

such will happen.” Project managers must focus this predictive capability on the project schedule and cost.

Direction of Solution: Common Cause and Special Cause Variation

All project managers understand that there is uncertainty in estimating project task cost and duration. They also know that there is variation in the cost and duration of actual task performance. Despite these uncertainties, customers and management usually require project managers to predict the cost and duration of their project. Project managers must also make project control decisions during project execution to attempt to bring the project to completion within these time and cost estimates.

Statistical Control

Shewhart and Deming point out that from a scientific perspective, statistics provides the only basis for prediction. Deming states [Deming, 1993], “It is only in the state of statistical control that statistical theory provides, with a high degree of belief, prediction of performance in the immediate future...A statement devoid of rational prediction does not convey knowledge.”

Task estimating and many task performance processes are subject to statistical control. (They better be; otherwise project plans are meaningless guesses!) Defining projects as ‘one-of-a-kind’ often leads to a false conclusion that project tasks are one of a kind. Most project tasks are done many times over by the people or contractors who do that particular work. Project estimating is a process performed many times. Specific project task output may differ (e.g., the equipment ordered or particular line of code may differ, even though I am filling out the same order form or using the same software development process and language). But, the basic task processes are most often repeated over and over by the performing agents.

Common Cause and Special Cause Variation

Dr. W. Edwards Deming writes, defining common and special cause variation, “A fault in the interpretation of observations, seen everywhere, is to suppose that every event (defect, mistake, accident) is attributable to someone (usually the one nearest at hand), or is related to some special event. The fact is that most troubles with services and production lie in the system.” [Deming, 1986] He further adds, “We shall speak of faults of the system as common causes of trouble, and faults from fleeting events as special causes.”

The differentiation is important to avoid two mistakes:

1. Ascribing a variation as special cause, when it in fact belongs to the system (common causes), and
2. Ascribing a variation or mistake to the system (common causes), when in fact the cause was special.

The problem with making these mistakes is that they both increase system variation. The funnel experiment, described below, illustrates how the first mistake always leads to increasing the variation in the result. In projects, this is manifest by unnecessary changes to the project, leading to cost and schedule over-runs.

The second mistake leads to a failure to remove the special cause of variation, with the potential for increased system variation. In projects, this is most frequently manifest as a failure to effectively manage discrete project risks. This failure means that risks are not effectively avoided or mitigated, again leading to project under-performance.

Dr. Shewhart invented control charts in 1926 to avoid these mistakes. Control charts track the performance of the important variable over time. Initial construction of the control chart provides information on whether the process is in statistical control; that is, free of special causes of variation. If it is not free of such causes, management must take action to remove the special causes of variation before prediction is possible.

Once the process is in statistical control, the control chart provides limits that clearly differentiate between variation that is common cause, and that which is special cause. Management takes action only on special cause variation. Figure 1 illustrates a typical control chart, with the upper and lower control limits. This chart uses the random data from the funnel experiment, described below, for 'x.' For a project, the variable x might be the ratio of task cost or schedule performance divided by the estimate.

The control chart shows the data as points, the average of the data, and an upper and lower control limit (UCL, LCL). Management should only react to points that demonstrate a special cause of variation. These are points above the UCL or below the LCL. None of the points in figure 1 are out of control, because it is a random process. You may use additional criteria to help detect special cause variation. [Kane, 1989]

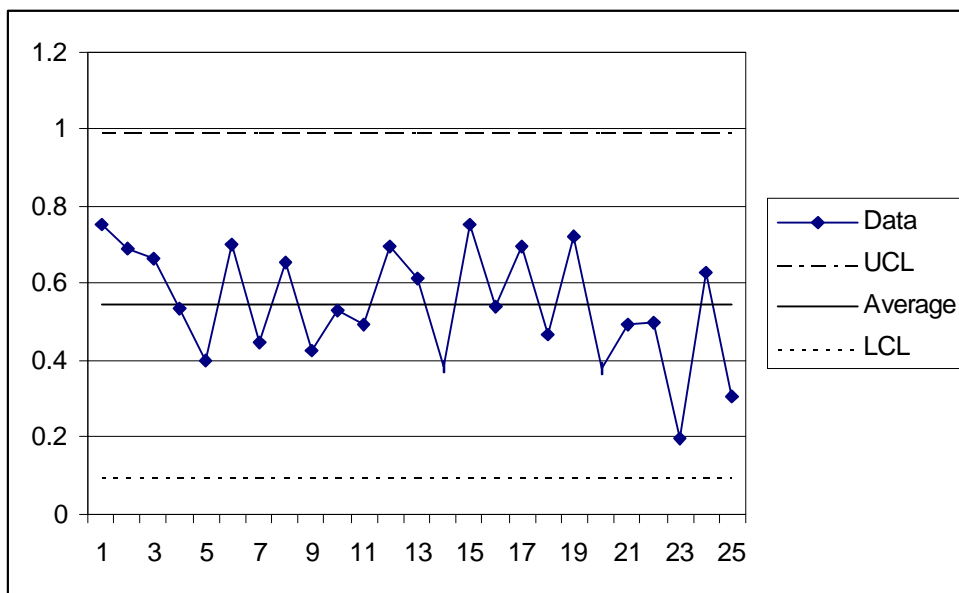


Figure 1: The control chart.

Distributions

Project managers frequently do not know the probability distributions for their project task cost and time estimates, nor do they have data on the actual task performance.

Recent articles in the PM network demonstrate a willingness to estimate these distributions as part of project risk management. [Schuyler, 2000], [Hulett, 2000]. Most people believe that the actual distributions for most project tasks look something like figure 2.

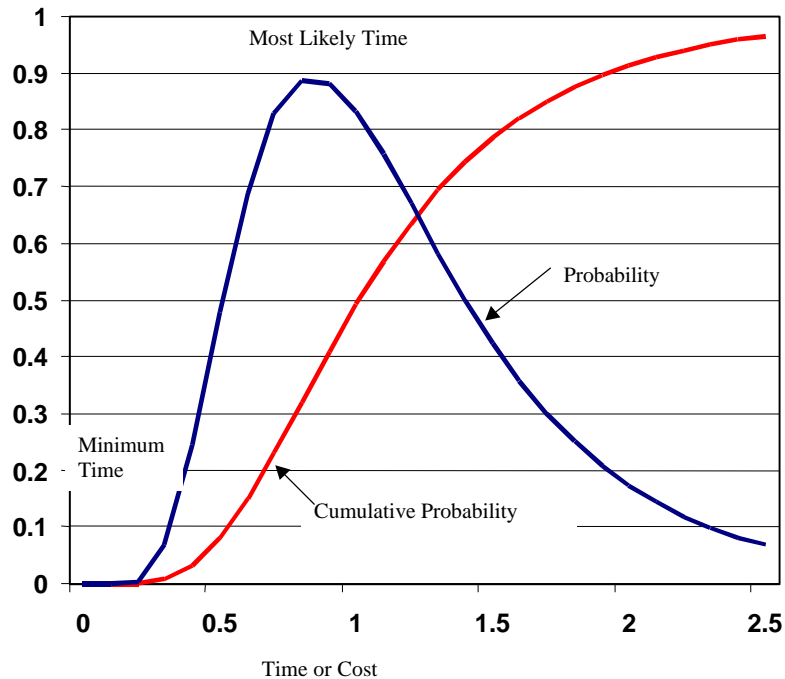


Figure 2: The probability profile of a typical project task (duration or cost).

One of the subtle but interesting facts that comes to light when you think of project task estimates as probability distributions such as figure 2 is that any point estimate has a probability of zero. The idea of accurate point estimates does not have real meaning. In other words, any (and all) point estimates are equally ‘inaccurate.’ For a discrete event, i.e., the outcome of a specific project task (duration, cost) all you can say is that, “if this task were performed many times, some number of the trials would likely fall between two limits.” Shewhart wrote that, “a statistician does not attempt to make any verifiable prediction about one single estimate; instead he states his prediction in terms of what is going to happen in a whole sequence of estimates...” For a project, this means we can make statements about a chain of activities, or the whole project, that we can not make about any individual task.

What we know

Project estimators usually have data on historical prices of project material. For some types of projects, they also have data that supports estimating the quantity of labor from parameters such as quantities of material installed or lines of computer code (which are also an estimate to perform some functionality.) The estimators may have nearly exact numbers on the pay rates of internal people that will work on the project.

Project task performers usually have a rough idea of how long similar tasks have taken in the past. Frequently, there is a basis for asserting that there is some minimum time in which the task could be completed. This duration estimate then frequently relates to the labor cost estimate

The meaning of the 'rough idea' of how long a task will take is a matter of some controversy. In most corporate environments, this means a time that you commit to; a 'high probability' or 'low-risk' estimate of the task duration. Attendance at many project review meetings, and evaluation of some project data supports a contention that most tasks complete on or near the estimated duration. (Only one task need be late on the critical path, with all others on time, to make the project late.)

What we usually do not (but often could) know

Estimating is something of an art. It is rare indeed to find that two estimators come to the same result when estimating a project. How many times are the bids equal on a project? Procurement personnel will tell you that fixed price bids usually vary by at least 20%, and sometimes much more.

Actual data for variation in project task performance exists in the construction and software industries. Some companies that do projects for profit acquire such data. The data is usually available from any project that used a computer-scheduling tool. However, I have found that the data is rarely evaluated. Thus, in many cases the task performance data is not available to create a control chart.

Deming's funnel experiment

Figure 3 illustrates an experimental setup described by Dr. Deming [Deming, 1986 and 1993] to cause an understanding of variation. The experimental set-up comprises a target on the floor, a funnel on a movable stand, and a marble to drop through the funnel. The aim of the funnel system is to cause the marble to land on the center of the target. For a project, the target is the committed project completion date and cost.

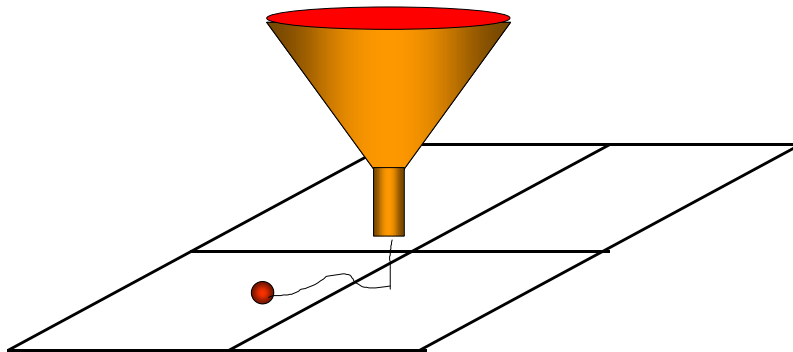


Figure 3: The Deming/Nelson funnel experiment.

The experimentalist determines the capability of the funnel system by centering the funnel over the target, and repeatedly dropping the marble through the funnel. She marks where the marble lands after each trial, resulting in the pattern illustrated by figure 4 (produced by computer simulation). You might consider the x co-ordinate on the figure as a project task actual time compared to an estimate, and the y co-ordinate as the task cost. (While cost and time often are correlated, in this simulation they are not. Cost and time may actually be negatively (accelerating project tasks increases cost) or positively (task time extension increases cost) correlated.)

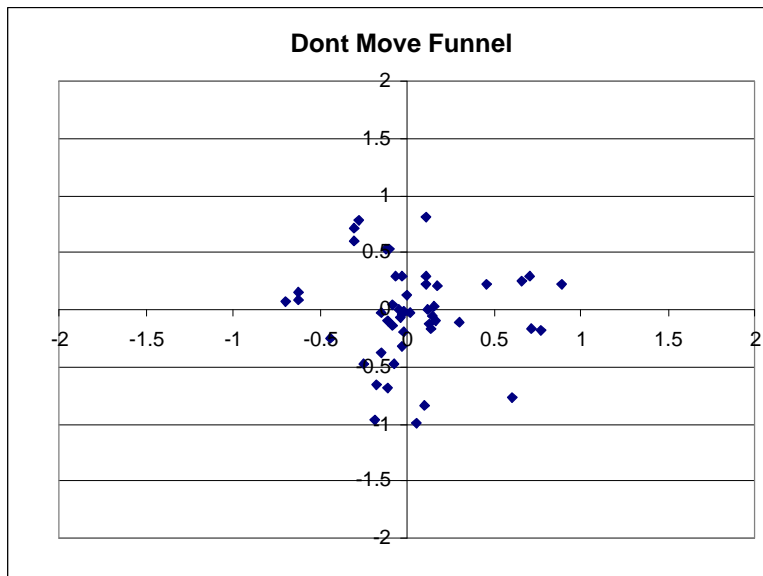


Figure 4: Results from rule 1: Do not move the funnel.

Project managers carefully monitor task performance. When the critical path changes (because variation in task performance caused a project path parallel to become longer than the previously identified critical path), management usually shifts focus and expedites the new critical path. Or, if a task or the trend of tasks shows some variation (e.g., 5%), project managers frequently must report on the variance, including identifying the action they will take to recover the variance. Let's try this in the simulation by moving the funnel whenever the marble misses the target. We will move the funnel by the same amount, but in the opposite direction, from which our task cost and time missed the mark (which you may consider as the project baseline estimate). Figure 5 illustrates this process, which Deming calls rule 2.

Figure 6 illustrates results from the simulation with rule 2. The spread of the points has increased! The increase was predictable because the variation was random to begin with. The correction process simply increased the variance of the result. Since the funnel movements match the amount of movement of the marble, the variance increased by a factor of two. Since the variance is proportional to the square of the range of the distribution, the spread increased by the square root of two, or about 40%. Obviously this was not a good management strategy.

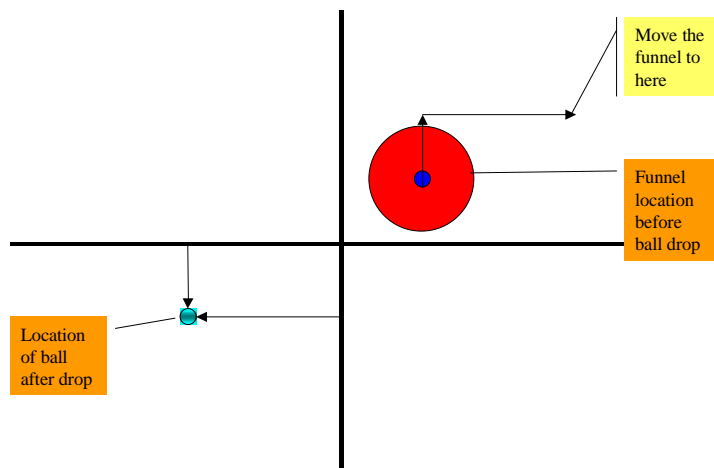


Figure 5: Rule 2: Move the funnel from its present position.

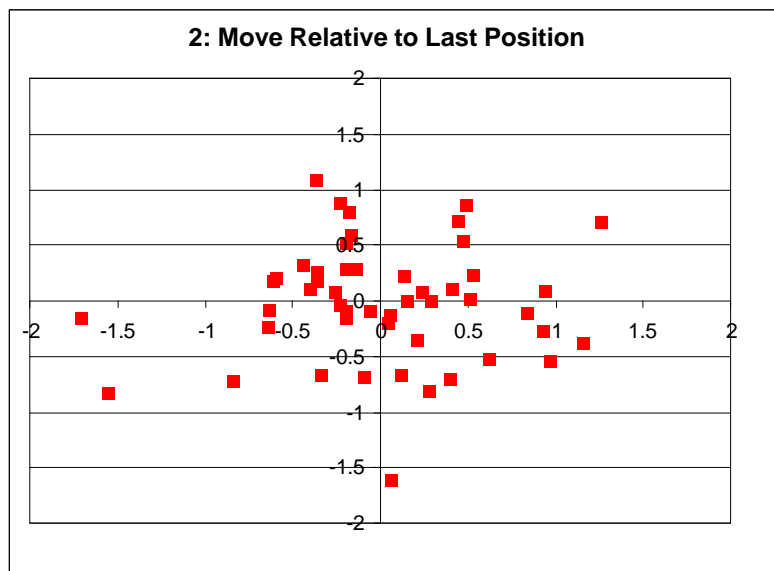


Figure 6: Results from rule 2: Move the funnel from its present position.

An alternative management action strategy is to move the funnel back to zero each time before making the adjustment. In a project, this might correspond to updating the project baseline with a change, or adjusting the plan to actual before taking the management control action.

Figure 7 illustrates the result of this management action. Note that the scale is expanded to accommodate the increased variation. The shape of this distribution varies with repeated runs of the simulation, but the general trend is to go off the chart in two directions. I believe that the explanation for projects that go seriously awry is related to this phenomenon.

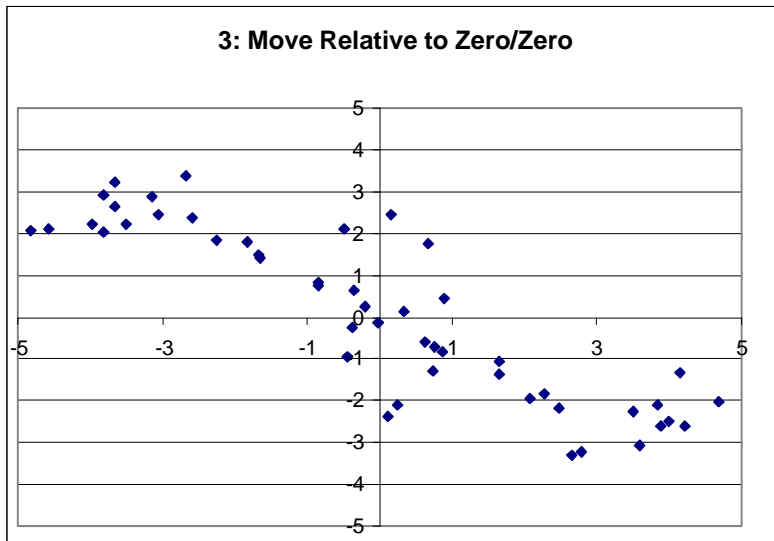


Figure 7: Results from Rule 3: Move the funnel from the origin.

Deming then tries one last strategy, which he calls rule 4. Rule 4 is to place the funnel over the last position that the marble landed. Deming compared this strategy to “worker training worker,” and to our legal system that is based on precedents. Shewhart noted, “when a judge makes a mistake, it becomes law.” In the world of projects, this might correspond to basing the estimates for your next project on the actual from the previous project.

Figure 8 illustrates that the results from this strategy also trend over repeated application to wander off the paper unbounded. Compared to rule 3, this rule usually runs off in one direction at a faster rate.

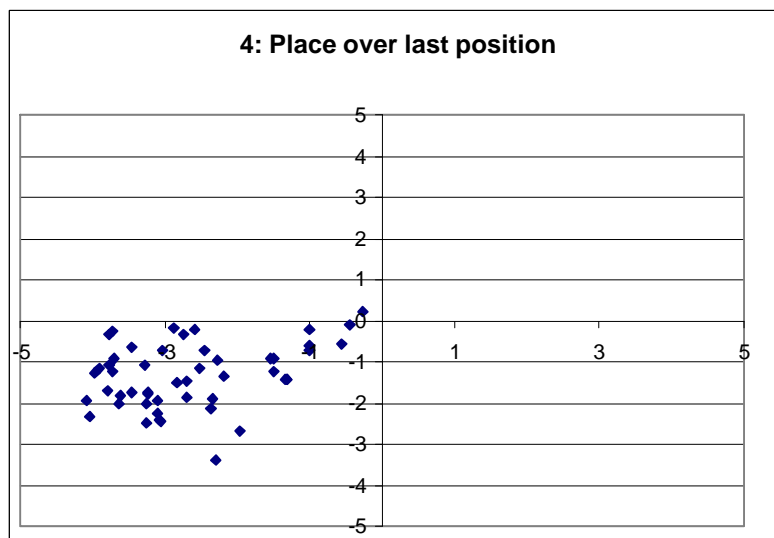


Figure 8: Results from Rule 4: Place the funnel over the last position.

I hope this illustration convinced you that the mistake of treating common cause variation as if it were special cause variation is a very serious mistake. It can cause great damage to project performance. Management manifests this mistake by management action, including expediting of tasks and processing project changes in an attempt to improve control. You should conclude that you need a means to separate common cause variation from special cause variation before you take action to 'improve' project performance.

Improvements to the PMBOK?

The PMBOK acknowledges control charts in chapter 8, 'Project Quality Management,' and even includes a figure (8-4) illustrating an example control chart of project schedule performance.

While the PMBOK makes reference to probabilistic models of project performance, actual project management practice seems to assume that project plans are, or can be, deterministic. Indeed, the common practice of ascribing start and finish dates to each activity in a schedule with hundred or even thousands of activities leads to misunderstanding the variability of task duration estimates and performance. (Early and late start and finish dates are not related to task duration variability, but are instead a result of the schedule logic.)

Stop Changing the Critical Path

The definition of critical path used in the PMBOK may contribute to treating common cause variation as special cause. The PMBOK definition of critical path notes, "the critical path will generally change from time to time as activities are completed ahead of or behind schedule." This is usually due to common cause variation. If there is value in defining the critical path, we should expect project management to do something when it changes. Taking action based on the changing critical path of the project, when the change is due to common cause variation, is an ongoing instance of mistake 1.

Differentiate Between Common Cause Uncertainty Management and Project Risk Management.

The PMBOK chapters on project time and cost management (6 & 7), the section on project control (10.3), and the chapter on project risk management (11) do not identify the difference between common and special cause variation.

PMBOK chapter 11, Project Risk Management, focuses on special causes of project variation, noting, "Potential risk events are discrete occurrences..." However, it then goes on to describe methods for common cause variation analysis; PERT and project simulation. It does not differentiate between the two types of variation.

The PMBOK's more detailed discussion of project quality management [Ireland, 1991] includes discussion of control charts. It does not relate control charts directly to project time and cost control, nor discuss the impact of the errors resulting from confusing common and special cause variation. Its definitions do not include common cause and special cause variation. It notes that, "Many projects, because of their short-term and unique character, do not directly use statistical concepts..." I fear that this statement my

lead some to believe that it is not appropriate to do so. As noted above, this perception is flawed because 1) project planning and execution is itself a process performed many times by project organizations, and 2) project tasks are usually performed many times by the task performers.

The PMBOK's more detailed discussion of project risk management [Wideman, 1992] also fails to differentiate between special cause and common cause variation. The discrete project risk analysis and mitigation methods should be separated from common cause variation to improve project success.

Recent articles in PM Network, dealing with the problem of uncertainty, [Ruskin, 2000], [Hulett, 2000], continue the trend of failing to differentiate between common cause and special cause variation.

How to improve?

CCPM

CCPM is a system to plan and manage projects based on all of Deming's elements of Profound Knowledge [Leach, 2000], including knowledge of variation. The critical chain approach greatly simplifies applying your understanding of variation to provide a kind of 'rough and ready' solution to managing variation. There is reason to suspect that Dr. Eliyahu Goldratt [Goldratt, 1997], the inventor of critical chain, may have taken this approach because he believes that few people will implement statistical process control. The critical chain method provides simple mechanisms to reduce the frequency of the two mistakes described above.

As a young method, CCPM is often misunderstood and misrepresented. In an otherwise excellent article on decision analysis, Schuyler [Schuyler, 2000] repeatedly (and erroneously) refers to CCPM as a deterministic method. CCPM's foundation in the Theory of Constraints derives from understanding variation and dependent events. Although a critical chain plan may appear to be deterministic, it is understood and applied otherwise by CCPM practitioners. People used to looking at schedules with start and finish dates for each activity may mentally add them to a CCPM plan. A CCPM plan only applies start dates to chains of activities, and a finish date to the project. The CCPM plan is a sequence of tasks with variable performance time. CCPM practitioners view the schedule buffers as probability distributions, with a cumulative probability of 50% at the start of the buffer and 90+% at the end of the buffer.

Critical chain reduces the frequency of the first mistake (reacting to common cause variation in the apparent critical path) by defining the critical chain to not change. By itself, this could increase the frequency of mistake 2. CCPM reduces the frequency of mistake 2 with schedule buffers.

The critical chain also reduces resource contention, a frequent cause of changes to the critical path. Although the PMBOK description of CPM encourages resource leveling, my informal research indicates this capability is used on less than 5% of project plans. The critical path can be ambiguous with resource-leveled schedules and Monte-Carlo simulations.

Schedule buffers are time allocations in the project plan used to manage uncertainty. A project schedule buffer at the end of the critical chain, sized using the estimated common cause uncertainty of the tasks in the chain, enables predicting a high confidence project completion date. Feeding Buffers in the project paths that feed the critical chain, sized the same way, perform the same function for those chains.

Buffer thresholds are set for the project and feeding buffers. These thresholds determine what action management should take, and when to initiate that action. The buffer action thresholds are the functional equivalent of the upper and lower control limits in control charts.

Feeding buffers greatly reduce the need to change the focus of the project team away from the critical chain. However, when a feeding chain has had a significant (i.e., special cause) delay, the feeding buffer will trigger action. CCPM feeding buffers solve the merging path problem addressed by many (usually in the context of PERT), e.g. [Hulett, 2000], [Schuyler, 2000], [Wideman, 1992].

Some applications of critical chain [Leach 2000] also use a cost buffer to aid in cost control, sized using the same uncertainty information as the schedule buffers, and incorporating action thresholds.

CCPM reduces mistake 1 by avoiding task start and finish dates. CCPM uses project path start dates, and the completion date of the project buffer. Project resources status tasks with an estimate of the expected time left to complete. The project manager uses buffer signals as the only action criteria.

I characterize CCPM as a 'rough and ready' approach to managing variation because actual process performance data (estimating process or task performance processes) is usually not used to size the buffers and decision thresholds. The most used buffer sizing method estimates the control action limits, and thus the variance, using predictions of low-risk and average task performance durations. Goldratt recommends a more simplified approach; dividing the usual task duration estimates in half to estimate the 50% probable time, and using half of the activity chain duration as the estimate for the schedule buffer. You can use actual task performance data and Monte-Carlo simulations to size buffers. The extent to which you use real data as inputs to the simulation and appropriate tools (such as control charts) to minimize mistakes 1 and 2 will be a competitive edge and future trend in companies that perform projects

Effective Critical Chain Project Management [Leach, 1999], [Leach, 2000] tracks the trends of buffer penetration (Figure 9). Buffer penetration is the ongoing forecast of how much of the buffer will be used. You calculate buffer penetration by adding the estimate to complete the currently working task to the estimate for the tasks not yet started. The buffer-tracking chart indicates management action thresholds for planning and taking corrective action. These thresholds, comparable to the control chart UCL, reduce the frequency of mistake 1, and provide reasonable assurance against mistake 2. Buffer tracking preserves the time history of the data, an important advantage of control charts over significance test statistics (which Dr. Deming abhorred). You may use some of the additional control chart signals directly on your buffer-tracking chart to determine management action thresholds, such as four points in succession continuously rising.

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