A Variable Time Project Planning and Control Model

Charles W. Butler
Colorado State University

Gary L. Richardson
University of Houston

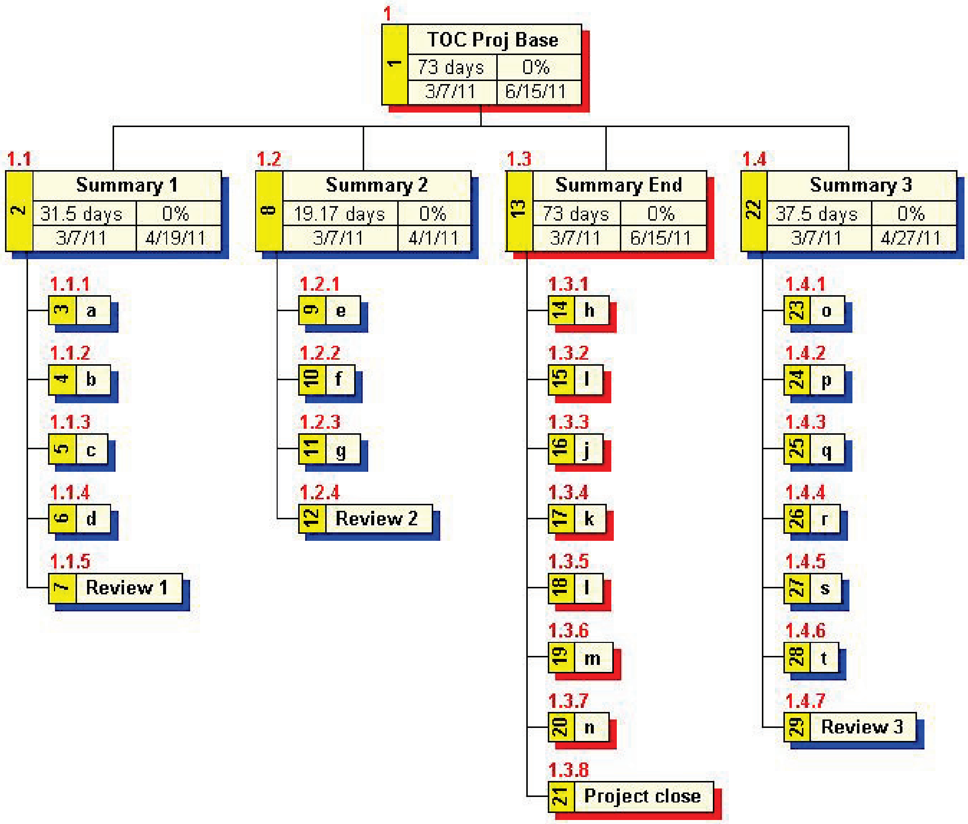
The typical method for project scheduling uses a single time estimate for all tasks. Yet, it is likely that each task will vary from that singular value as will the planned project completion date. Rather than using a deterministic date that is inaccurate, it is suggested that a more rigorous model use probabilistic time estimates that support processes yielding a more desirable answer. This paper will illustrate a method using variable time estimates associated with a Critical Chain Theory implementation to produce project schedules that have potential to be finished on schedule and actually shorten traditional cycle times.

INTRODUCTION

Projects have long been characterized by broad variations in functionality, cost, schedule and human resources when compared to the original plan. Management and future users of the project output are often frustrated by this apparent lack of project management skill in prediction and control. To that end, the goal of this paper is to explore some of the common reasons for these situations and illustrate a design structure for improving both overall completion cycle time and predictability. Unfortunately, another related conclusion will be that typical project management support processes do not adequately deal with this issue.

In order to conceptualize a solution to these primary outcome sources, we first define what they are and how they cause variation. A start point for this definition is to assume that projects have some form of valid scope definition. Failing that requirement, we would have to start at a much more elementary level which does not relate to the basic planning concept in focus here. Traditional project management theory describes scope definition through the Work Breakdown Structure (WBS) and its supporting level of detail. Within this umbrella structure we describe the work to be performed in completing the project output goal. Figure 1 shows a skeleton view of such a definition. This figure has been augmented with details regarding duration and cost for the various work units.

FIGURE 1
SAMPLE WBS



At the top of the WBS in figure 1, we see the total project that is decomposed into its four major component deliverables and associated lower level work elements. The bottom layer of this WBS contains elementary work units, called work packages, which must be accomplished to complete the project. In the traditional management model, actual completion and resource status data for the work units would be collected and any variance from plan used to guide the management control effort. Unfortunately, this approach implicitly assumes a level of stability that does not typically match reality and therefore bypasses an effective analytical management and control approach. In order to deal with this instability of work task, a different approach to managing task execution is needed.

The process of managing project schedules is obviously complex and impacted by many factors. Some of these factors are technical in nature, while others are more behavioral. However, regardless of the driving factor, the key concept described in this paper is that time planning is not a deterministic metric. It should be viewed more as what it really is; that being a probabilistic event. This view is not the traditional norm for many reasons. One key view is that stakeholders viewing the project want a fixed date and not probability distribution saying that there is a 75% chance the project will finish in some range of dates, even though that is a more accurate predictive statement. The fact is that any specific date is almost by definition inaccurate. If the project manager (PM) is charged with being "an honest broker of information," why should the PM not try to provide a more accurate projection? In reality a better management process is obtained by allowing this assumption.

MODEL COMPONENTS AND GOALS

The list below outlines a collection of classical and contemporary ideas packaged together which are deemed important components for improving task throughput and prediction times for project performance. Specifically, the following elements are included in this model.

1. Variable time work unit estimates
2. PERT-like probabilistic analysis of overall task completion
3. Modified Critical Chain Theory concepts for internal plan development
4. Earned Value analysis of status
5. Microsoft Project (or some similar software) for data manipulation

When packaged as a collection of techniques, the package offers potential benefits for project estimation, management, and control including the following:

1. Improving the project cycle delivery time
2. Providing a better match of the project performance by recognizing variable time estimates
3. Dealing with well known estimating psychology that creates padded time estimates
4. Providing a clearer control view of project status with a higher potential for achieving a predefined completion date

As with any process model that deviates from the accepted norm, adding new techniques into the management equation will represent a change in organizational culture. That in turn means that the change process must be carefully engineered to be accepted by the future project teams and management. Richardson offers more details on these underlying points (Richardson, 2010).

The list above suggests several new key steps that are now required to create the project plan. The first recognized step involves the work estimation process. If the task time estimate implies the work can be accomplished in two weeks but there is some obvious uncertainty, the resulting plan value cannot just be expanded to take that uncertainty into account. If all tasks in the project are padded this way it is fairly easy to see what happens to the overall schedule. Not so obvious, the result of this approach leads to further time delays as a result of the various work groups recognizing the padding and tending to procrastinate in actually starting the task thinking that they have extra time. As a third causal issue, multitasking also seems to be a major factor in this delay process—i.e., trying to satisfy all work requirements by assigning multiple tasks to individuals who then try to keep all of the work balls in the air while doing none of them efficiently. Later, once the task is started the project team often discovers that it really does have uncertainty and the time extends again even when the original time was padded. Task padding gives the illusion of extra time and procrastination amplifies that result. These organizational tendencies dilute the overall efficiency of the project execution. This cultural phenomenon of work scheduling is an organizational work discipline issue that must be dealt with as part of this model implementation. In short form the project must be looked at as a relay track race with sequential work tasks being the individual events and not a group of bloated sequential time work units through which the team procrastinates. In order to improve this process the goal must now be to focus on executing each work item using median time estimates and proceeding to the next task as quickly as possible. We also now have to anticipate task overruns on probabilistically 50% of all tasks since they are estimated at a 50% median value. Obviously, the idea of overruns being normal will take some selling to implement.

The relay track meet metaphor comes from Critical Chain Theory which was originally conceived by Elijah Goldratt and matured in project use by several industry practitioners (Goldratt, 1997). These pioneers quote impressive improvements for project cycle times in the range of 25% when the theory is properly applied (Leach, 2004, p.18). If one believes these outcomes that alone should be sufficient evidence for looking deeper into this concept. However, it is the authors' opinion that many organizations are not process or managerially mature enough to implement the full scope of the Critical Chain Theory. Leach and Patrick offer a good description of the model theory and basic components, but they do not show sufficient operational mechanics necessary to implement these concepts (Patrick, 1998 and Leach, 2004). The approach taken for this paper is to use simplified design strategies that will achieve much of the model value while avoiding the full implementation complexity that keeps many organizations from pursuing the idea. So, realize that the model presented here is a simplified subset of the Critical Chain Theory that attacks the main problem core and mitigates the causal elements inherent in schedule overruns.

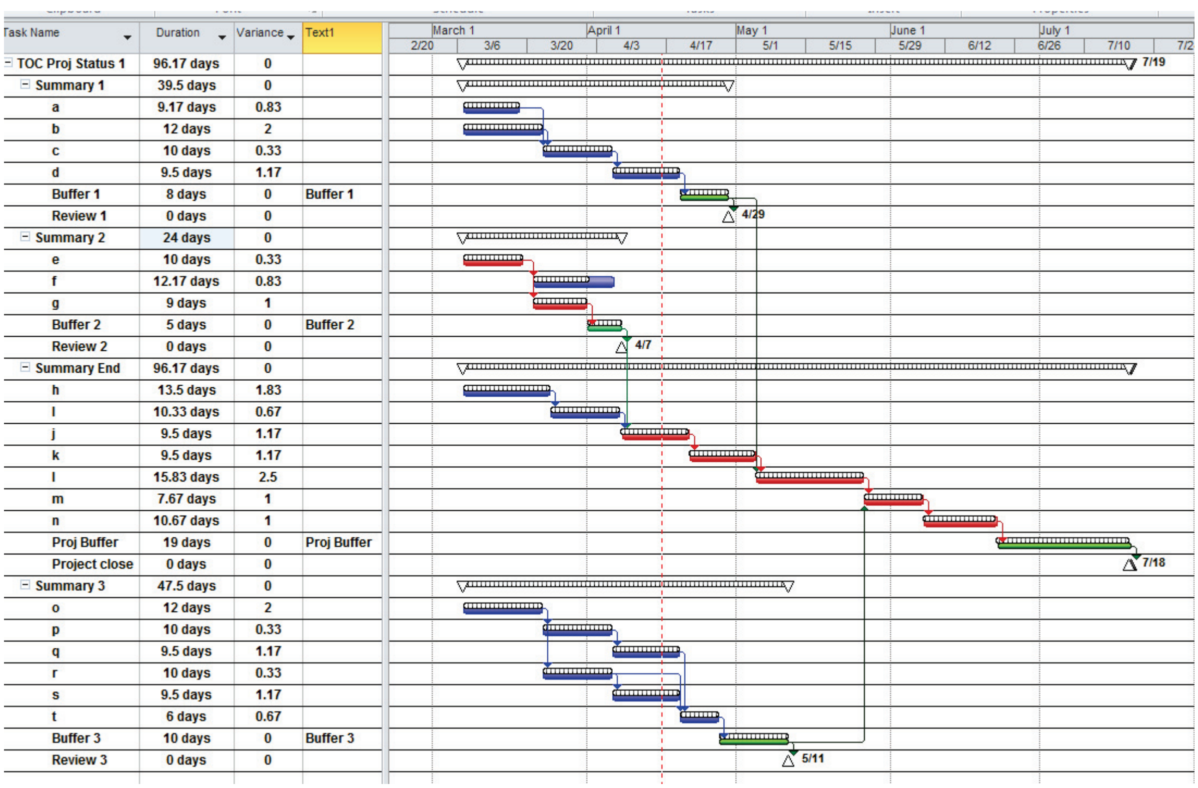
The following six items represent the design mechanics for the model. Each design mechanic is an essential step in the process for establishing a project plan.

1. Task estimates are three-time range estimates (optimistic, most likely, and pessimistic) with the actual plan value being the median time of that probabilistic range. This approach is designed to take away the feeling that the plan time as any padding. In fact, it would be expected that each task has a 50% change of overrun. The goal is to remove procrastination from the process.
2. Resources for the project will be managed in such a way that critical activities will be given priority and this will require more careful tracking of task status given that they are not scheduled on a fixed date, but to start as soon as the predecessor is finished. This goal focused on getting needed resources to the task as needed.
3. The project will be decomposed into multiple "work chains" based primarily on major Work Breakdown Structure leg segments (see figure 1). The critical path will be defined as the primary chain, but other feeding chains will also be recognized. All defined chains will be protected from overrun by buffers which will protect the overall project schedule from overrun. All of this process is adapted from the Critical Chain Theory, but modified here to simplify implementation. The key design challenge here is to identify the work chains. Recognize that not all projects will be as simple to structure as this example.
4. The various chain buffers will contain both time and cost reserves which lie outside the control of individual work groups. These will be used to absorb variations in task performance. As the project dynamics occur the buffers will be adjusted to show performance status. In this form a major aspect of project performance will be buffer consumption status. This is a new view to project control.
5. The approved project plan will be baselined (frozen) in the same fashion as the traditional project model and from this base view Earned Value (EV) parameters will be calculated based on the expected time estimates. The impact of this modified calculation method will require that the EV metrics be interpreted somewhat differently, however the basic parameter interpretation is the same as the classical one and maybe more relevant. More research on this interpretation will be needed to confirm how the EV parameters should be evaluated, but clearly the numerical values will be different than those computed in a traditional format.
6. Project planned completion date will be protected by a critical path buffer. Throughout the structure, sizing of the various buffers will require some experience to define accurately, although the initial variability data could be used for buffer sizing using classical PERT variance theory. There is some question as to the adequacy of this as a math problem rather than a project dynamics view. Once buffer sizing experience is achieved there is reason to believe that actual completion prediction dates will be more accurate than previous methods and the overall project duration should be shorter than found using traditional padded estimates. A major cultural issue related to this comes from the recognition that organizations have historically frowned on visible buffers as they appear to be fluff and not related to real events in the project. In this new model all padding is visible in the buffers and has been derived based on reality type assumptions and not just to arbitrarily extend the length of the project, but rather to recognize the estimated variability of the work.

SAMPLE PROJECT PLAN

Figure 2 translates the simple WBS shown in figure 1 and converts it into a comparable project plan that contains four distinct "work chains." In this simplified case the work chains are reasonably clear; however in some more complex plans that will not be the case. Regardless, the concept is to identify feeding (non critical) and critical path work chains and protect each chain schedule with a buffer. In figure 2, the feeding buffers are labeled buffers 1, 2 and 3, while the critical chain buffer is labeled "proj buffer." This figure illustrates how a project that is overrunning its expected times still can meet the defined completion dates so long as the various buffer sizes are adequate to protect their respective chains. Note from the Gantt bar view that buffers 1, 2 and 3 are protecting their respective feeder chain from impacting the critical path schedule at their intersection point and the project buffer is designed to protect the critical chain schedule. Buffer sizing remains an art form, but that should mature with specific project type experience. A rough rule of thumb is that the buffer would be sized at 50% of its chain value. The figure buffers are sized at approximately 25%. This sizing can be compared to the chain variance calculations for reasonableness.

FIGURE 2
PROJECT PLAN WITH "WORK CHAINS"



PROJECT CONTROL MECHANICS

Since the overall project work is now viewed as a series of chains, each one moving as fast as possible, the schedule date for any one work item takes on a lesser meaning. Remember that the duration times shown are actually expected times from the probability distribution. As a result of this the basic control mechanic is to ensure that resources for following tasks are on standby waiting for each probabilistic task to complete and that the buffer is not being consumed too quickly. One of the key internal status reporting requirements is now a more dynamic estimate of completion for each active task.

In order to support the schedule, resources will need to be waiting in the same manner that a track relay runner waits for the baton from the predecessor runner. This also means that all resources will be focused on the upcoming task at the expense of any other work. The illusion of all things going on at the same time with multitasking is now gone. For this technique to work properly, it will be necessary to optimize the allocation of resources to tasks and sub optimize utilization of resources. This means that the waiting time will require work assignments that can be dropped quickly as their chain event finishes. In addition, work tasks will need to be prioritized to resolve competing demands for the resource. Normally, a critical path task would be supplied resources before a feeder task.

A second control strategy is linked to buffer status evaluation. Since buffers are protecting the plan from overrun it is vital to monitor their status as they signal possible overruns in that chain. Figure 3 illustrates the basic logic for evaluating buffer status. As the project unfolds we anticipate the buffer being used. In the sample case the chain is shown as four tasks of five units each with an initial buffer of ten units. As the project has unfolded the first task actually took twice as long as the expected time calculated for it (not unexpected). The original buffer was set at 25% of the chain or ten time units. At this status point we have completed 25% of the chain, but consumed 50% of the chain buffer. The tracking metric would be calculated as 200% and thus send a signal to the project manager that this chain could be experiencing an issue.

FIGURE 3
EVALUATING BUFFER STATUS

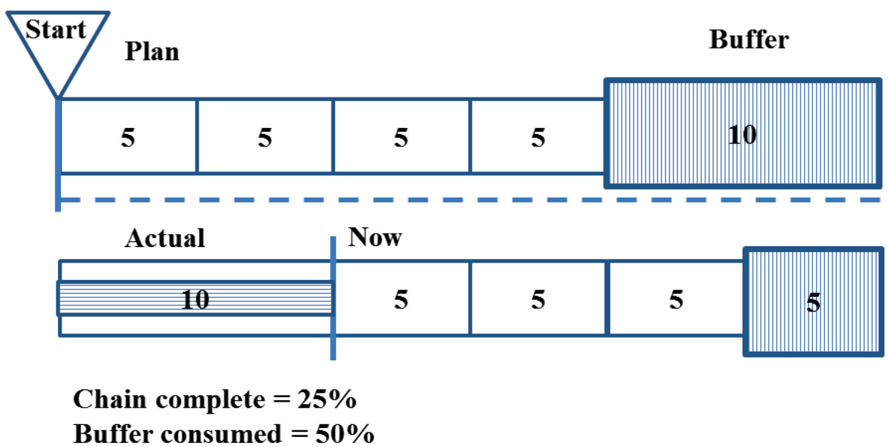
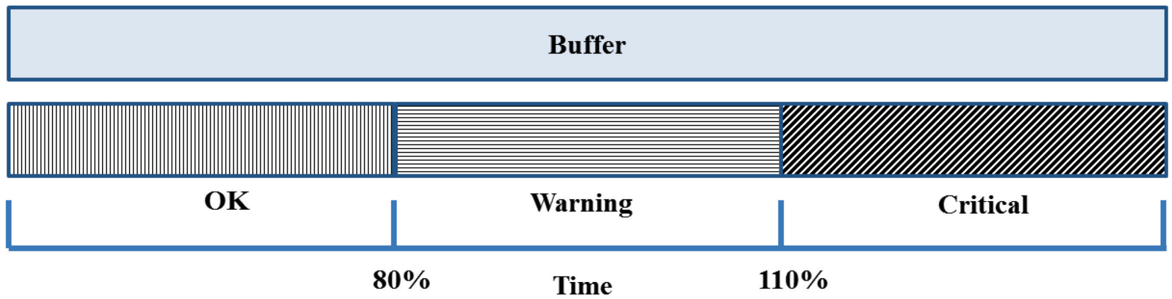


Figure 4 illustrates how this concept can be turned into a color coding for buffer status (In this figure, texturing is used instead of coloring). Arbitrarily, a buffer ration of 80% to 110% could be labeled with a warning. Values above 110% would be labeled as critical and require analysis, while those below 80% would be assumed in control and indicated as OK. Once again experience would be used on defining the status segments. The important idea in this approach is to recognize that plan versus actual task performance is not now a valid operational method, rather status of buffers becomes the critical event.

A less obvious implication of the buffer content is that it contains budget dollars as well as time. The budget amount would be estimated as an average per time unit cost for the chain and its role is to cover the resource side of overruns just as the time dimension did for the schedule. In both cases as a chain overruns the plan a buffer would be "eaten," meaning traded off to reflect the impact of a chain task cost and time overrun. Actual costs would also be collected for each task as performed and variances would reflect how far from the expected the task took. This information could be used in future projects to refine the estimating and buffer sizing logic.

FIGURE 4
COLOR CODED BUFFER STATUS



A third issue resulting from this method is the impact on Earned Value (EV) calculations that results from the paring down of the original task estimate. Recognize that this will make the resulting EV parameters compute with lower values since the base planned value is lower. Traditional calculations measure performance from a heavily padded original estimate that accounts for overruns, whereas the chain model handles the overrun in the buffers. Because of this, comparative values are likely at least half of the traditional value so an on time schedule of 1.0 that would represent exactly on plan, the new calculation might be 0.5 for the same case. Just as the project management industry is being accepted as a performance measurement tool we are now proposing a set of mechanics that will significantly change their interpretation. Preliminary analysis of this indicates that we will need to re-examine how the EV parameters are used. As long as the methodology is consistent its general analytical value remains, but not as published in current literature.

Throughout this discussion various items have been mentioned that deviate from the traditional procedural approaches to project performance measurement. There are three significant organizational changes that will have to be embraced before this model can be used successfully. These are:

1. Management approval for the use of visible buffers in the project plan and training to help all understand that these are not extra time and cost padding schemes
2. Utilizing work unit estimates that have a 50% probability of overrun are going to be a tough sell to the performing organizations. Historically, overruns were viewed as negative events. Now they will occur very frequently and should not be viewed negatively. This will require management training to break that paradigm.
3. Meaningful quantitative status measures can no longer be planned versus actual variances, or even Earned Value for that matter. The new key to performance measurement is now the status of the various buffers.

IMPLEMENTATION CONSIDERATIONS

The best method to sell an organizational, change initiative is for the new method to show positive results. This suggests that early implementation efforts should be focused on small projects with willing team members who will trust that overruns as described here are part of the new process. Once the traditional views are dealt with the following set of mechanics need to be developed and tested:

1. Buffer sizing for feeder and project chains. It is recommended that 50% be used in the beginning and then hopefully decreased with experience. A generous buffer size on the test project will help sell the outcome.
2. Estimating techniques need to include three time estimates and the project team needs to understand what that means along with the notion of expected time used in the plan rather than a pessimistic padded time.
3. A restatement of EV role and quantitative interpretation will be needed. It has been indicated here that experience is required to normalize how to interpret these

parameters in the reduced time work unit mode. More research is required for this beyond what has been described in this paper.

The complexity level of project status reporting reflected in this model clearly requires something beyond manual methods. The research for this article was supported by a Microsoft Project 2010 model. However, this can be further aided by a custom macro to process the three time estimates and related variances needed for analysis. Brian Kennemer created a macro for this purpose and the author can supply an updated version (Kennemer, 2009). The same calculations can be made using spreadsheets, but that adds another level of detail one would rather not have to deal with. Use of an automated technique such as this also provides the capability to use "what if" type comparisons during the early learning phase of the technique. Issues such as buffer sizing, color graphic status, and reporting formats can be handled much easier in this mode.

CONCLUSION

This brief overview of a Critical Chain related project design model has attempted to highlight how such a model can be implemented in the real world without taking on the full complexity of the Goldratt theory and yet achieve some of the major benefits from that effort. The role of variable time estimating comes from classical PERT models of the mid-1950s and the underlying review of buffer sizes can also be examined from this classical model. However, we also see that time estimating accuracy involves more than just the three time estimates. It is necessary to focus the organizational culture on timely resource allocation related to task pursuits. No longer can a task estimate be multiplied by some padding constant to cover potential time overruns. The Critical Chain concept dictates that overruns will occur since the time estimates were made with the assumption that you only have a 50% chance of achieving the stated time. We see in the feeder and project chains that buffers are used to protect the schedule for each segment of the plan. From an architectural point of view this makes logical sense, however the visibility of such buffers has been historically viewed as excessive time padding. This means that they are not thought to be valid management techniques. Education will be needed to show why they are necessary and not viewed as simple time padding.

This overview of the chain model has illustrated techniques that are counter to the traditional methods of project planning and control. Primarily these significant impact areas are:

1. Probabilistic time estimates used rather than deterministic
2. Use of designed and visible internal chain buffers to protect the plan
3. Management of the project resources will have to be more carefully controlled than the current methods, however this is one of the processes most needed for overall improvement
4. A control philosophy more oriented towards buffer management than planned versus actual task status since task completion is not a deterministic variable any longer
5. Earned Value Management is just now becoming a widely recognized project performance measurement strategy for the traditional project, however the model described will change how that process needs to be implemented
6. Planning and control complexity related to this model is higher than the traditional Gantt bar oriented version that does not reflect reality

For the contemporary project manager this model view brings a conundrum. Should you just continue to use a model technique that clearly does not reflect the real world but is acceptable to the organization, or do you attempt to move your organization to a higher level of project management understanding. The motivation to move in this direction is driven by a belief that projects need to become more time efficient and management would like to have them finish on some predictable date. This method has that capability if one assumes that the three time estimate process is valid, buffer sizing can be done properly, and resources are carefully managed for the tasks. Also, the net result will be a project that finishes at least 25% sooner and with a lower cost. That is the carrot that should cause these issues to be addressed.

The design driver for this model is its thrust into the heart of why projects overrun. Organizations today are searching for methods that will reduce project overruns and cycle times. In many cases one might view some of the typical redesign efforts as "moving the chairs around on the Titanic." One must recognize that it will be necessary to go to the source of the leak to stop the fatal result. Likewise, unless we address the fundamental reasons for projects to behave the way they do today little improvement will be noted. The Critical Chain logic represents one of the best conceptual strategies to achieve that goal, but not one to be successful without changes in the underlying organizational processes and work culture. These concepts are so compelling that it is important for the modern project manager to understand both the power and operational complexity related to it. Hopefully, this abbreviated view will help stimulate that interest.

REFERENCES

Goldratt, E. (1997). *Critical Chain*. The North River Press Publishing Corporation.

Kennemer, Brian. Three Point Estimation Macro,
http://blogs.technet.com/projectified/archive/2009/11/24/3296207.aspx.

Leach, L. (2005). *Critical Chain Project Management*, *2nd Ed.,* Artech House Professional Development Library.

Patrick, F.S. (1998). Critical Chain Scheduling and Buffer Management: Getting Out from between Parkinson's Rock and Murphy's Hard Place, www.focusedperformance.com/articles/ccpm.html

Richardson, G. L. (2010). *Project Management Theory and Practice*, CRC Press.