

CRITICAL CHAIN RESOURCE MANAGEMENT

MOVING FROM A PROJECT TO AN ORGANIZATIONAL
ADOPTION OF CRITICAL CHAIN PROJECT MANAGEMENT

By

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For

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ABSTRACT

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In the spring of 2007, a strategy was developed with the intent of getting my company's division to adopt Critical Chain Project Management (CCPM) as a way to create a long term competitive advantage for the site. As part of this strategy, in the summer and fall of 2007, a single pilot project was conducted to identify the changes necessary to successfully execute CCPM in this work environment. While the pilot was successful in identifying the conditions necessary to execute CCPM, afterwards concerns surfaced about whether a piloting approach was a sustainable method for attaining widespread adoption of CCPM at the site or if it could, unintentionally, preclude it. As a result, a series of interviews were conducted with professionals in the Theory of Constraints (TOC) community to gain insight regarding these concerns and to identify proven implementation strategies as well as the education and training sufficient for obtaining organizational adoption of CCPM. This paper synergizes the information obtained from those interviews to identify the strategic, tactical, and execution actions necessary and sufficient to achieve organizational level adoption of CCPM.

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LIST OF ACRONYMS

BCR – Buffer Consumption Rate

CCPM – Critical Chain Project Management

CCRM – Critical Chain Resource Management

CPM – Critical Path Method

CRT – Current Reality Tree

DE – Desirable Effect

EC – Evaporating Cloud

ERR's – Execution Run Rules

FB – Feeder Buffer

FM – Functional Manager

HR – Human Resources

PB – Project Buffer

PE – Project Engineer

PM – Project Manager

ROI – Return On Investment

SME – Subject Matter Expert

TOC – Theory of Constraints

UDE – Undesirable Effect

SECTION 1

INTRODUCTION, BACKGROUND AND PROBLEM STATEMENT

1. Introduction

Despite the successful completion of my division's first single Critical Chain pilot project in December 2007, a critical review of the piloting approach as a method for gaining adoption of CCPM at the organizational level revealed some disturbing negative side effects. While it is expected that every pilot project will have some issues/concerns stemming from its execution, concerns raised after completion of the pilot called into question whether a "Piloting Implementation Strategy" was sustainable in this environment over the long haul and whether continuing to model this approach could ultimately jeopardize organizational adoption of CCPM at the site. To validate these concerns and determine the proper strategy for gaining organizational level adoption of CCPM, a series of interviews with professionals in the Theory of Constraints (TOC) community were conducted between January 18 and March 10, 2008. These interviews addressed the problems that surfaced as a result of evaluating the "Piloting Implementation Strategy", and identified strategic, tactical, and execution level strategies that have proven effective within both my company and private industry for gaining wide spread acceptance and adoption of CCPM.

2. Problem Statement

While the pilot team completed their project well within the project buffer and enjoyed all of the benefits provided by Critical Chain Project Management, others credited the special attention given to the project by management and the employees as the main reason for its success. They did not give credit to, nor acknowledge, the behavioral changes caused from proper CCPM planning and execution.

My interviews revealed that this was a common response from skeptics of CCPM. In fact many of my interviewers mentioned that upon learning of the positive results of the pilot, individuals not involved in its execution discounted its success, stating that regardless of the methodology used any project receiving that much attention would achieve similar results. In addition, the following negative reactions came from the piloting approach and were specifically mentioned by individuals within my division:

- The Execution Run Rules (ERRs), which were created specifically to create an environment capable of protecting the execution team from bad multi-tasking, may not be sustainable over the long run.
- CCPM Planning and Execution Run Rules were discounted as merely representing good project management practices as opposed to it being credited for the behavioral changes CCPM caused which contributed to the success of the pilot.

- Once outside the pilot, several team members of the pilot expressed frustration with having to return to their old, multi-tasking environment.
- A fair amount of time was required to educate and train the team on CCPM philosophy and planning processes.
- Despite the amount of time spent educating and training the pilot team, upon its completion, several members were still unclear how the pilot was able to achieve such positive results.

The aforementioned problems uncovered the following areas which must be addressed if organizational adoption of this method is going to be successful:

- The affect of using CCPM pilots as an implementation strategy and their potential for jeopardizing organizational adoption must be understood and addressed.
- Proven, effective strategies for obtaining active support of CCPM must be obtained.
- The role management support plays in defining the environment and implementation strategy must be clearly understood.
- The impact the environment has on CCPM must be understood and addressed.
- The appropriate messages that need to be communicated to the various CCPM stakeholders need to be identified.
- Effective education and training methods for obtaining support for CCPM adoption must be identified and executed.

SECTION 2

Strategic Level Strategies

1. Obtaining Management Support

One area where there was universal agreement among the TOC experts interviewed for this project involved the importance of having active senior management support for CCPM. It was mentioned that the magnitude of the impact Critical Chain Project Management can have within an organization is limited by the level of management support. The more clearly senior management can visualize a direct relationship between implementing CCPM and achieving their most important goals, the easier it will be to gain their support for adopting CCPM management methods. The level of management stakeholder support in the organization will, in turn, define the environment in which CCPM will be allowed to function.

If, for example, the highest level of support resides at the first line manager level, then their particular environment will limit CCPM implementation to single projects, and dictate the processes and Execution Run Rules (ERRs) their team must develop to protect themselves from reverting to their old habits for executing their projects. However, even with these protections in place, the team will find it difficult to sustain CCPM because of organizational pressures to be responsive to various “customer” requests that flow down from higher levels of management. Since no one wants to disappoint their boss, without a conscious effort to change the way project resources are managed, the support for CCPM will tend to gradually erode. In general, the

higher the level of active management support, the broader the environment and, therefore, the greater the degree to which CCPM can be adopted and positively impact the organization.

During its formational stages ERRs will most likely be required. However, when CCPM is actively supported from higher levels of management in the organization, there tends to be a much broader effort across the entire organization to identify and eliminate processes and procedures that are counterproductive to successful CCPM implementation. In these situations, the need for many of the ERRs is reduced. The TOC industry experts I interviewed agreed that this situation better supports widespread acceptance and adoption of CCPM and provides an environment in which CCPM is best able to survive and eventually thrive within the organization.

Assisting management to create its unique vision of how CCPM can benefit them and their organization is, perhaps, the most challenging part of the adoption process. Another universal statement expressed by the TOC professionals interviewed was that while it is relatively easy to understand the logic behind why an organization should adopt CCPM (e.g. better project performance, more projects performed with the same resources, etc.), this general approach is typically insufficient for obtaining anything more than passive support. My interviews uncovered that managers must be able to visualize and articulate on a more personal level how this new method will enable them to achieve their most pressing goals before they will become actively engaged in adopting CCPM. Eliyahu Goldratt was very familiar with this reality,

which explains why his books on the Theory of Constraint applications, such as *Critical Chain*, use a Socratic writing style. This story telling style is one of the best ways for enabling others to discover, and define for themselves, how they can benefit from implementing CCPM. Another approach which has proven effective is asking questions that highlight those benefits of CCPM which are most likely to be of interest to senior managers, and therefore encourage them to develop a unique, personal response. Some examples of questions which were identified as generally being of interest to senior managers include:

- What would it mean to our organization if we could consistently deliver our projects 25-50% ahead of schedule while meeting our customer's cost and quality commitments?
- If we dramatically improve our project performance what would that mean to our ability to compete in our existing market?
- What would be the benefits to our organization if we gained a reputation in the market for consistent, high quality performance on our projects? What impact might it have on our ability to win new contracts?
- What would uncovering 25-50% additional capacity from our existing workforce mean to the various departments in our organization (Human Resources, Engineering, Contracts, Finance, etc.)? How might the savings associated with this additional capacity ripple through to positively impact other aspects of the organization's operations?
- What would it mean to the organization if you knew what the most constrained resources in the organization were at any given time and could

then use this information to ensure they were constantly focused on the most important project for the site for any given month, week, or day?

- What would be the impact to both managers and employees if everyone knew their top three work priorities each day and had a clear understanding of how their work contributed to the business goals of the organization?
- What do you think would be the impact to employee morale if they were given responsibility for the day to day direction of their projects, knowing management assistance would be provided only when absolutely necessary?
- How would having immediate access to information on all projects and organizational priorities improve the management of our resources?

Questions such these enable others to visualize and discover for themselves reasoning that is sufficient for them to enthusiastically support adoption of CCPM.

Another good approach mentioned by several of the individuals I interviewed that has proven effective for enabling others to visualize the benefits of CCPM is telling simple, relevant stories of where and how CCPM has had a positive impact on an individual, a team, a department, a division, or a company. Finally, providing reference materials and contact information of individuals, which have experience using CCPM that the manager can personally identify with, can be invaluable in obtaining management support. Industry experts agreed that unless, and until, a person can clearly define their own “why” for adopting CCPM, attempts to gain acceptance will make the CCPM proponent feel as if he or she is continually “selling”, justifying or proving the merits of CCPM, none of which in the end will be

sufficient for gaining acceptance. Specifically, it was mentioned that once upper management has clearly defined their “why” for implementing CCPM, you can then begin focusing on “how” to implement it, knowing that the challenges that will surface will be easier for management to overcome.

While all of the experts I interviewed agreed it was a good idea for senior management to clearly see the relationship between implementing CCPM and the bottom line impact to their organization, there was some disagreement on how best to achieve it. After defining their compelling reason for wanting to adopt CCPM, the TOC professionals I interviewed from outside of my firm felt very strongly that senior management needed to conduct a feasibility study to identify the bottom line benefits to the organization as well as the potential risks its implementation might impose. Specifically, they felt that the best way to gain widespread acceptance by senior management required them to determine the potential Return-On-Investment (ROI) for the organization as well the potential risks associated with adopting CCPM. It was suggested that prototypes should then be identified and executed for testing the mitigation strategies associated with these risks. Once the magnitude of the ROI is clearly understood by senior management and the risks have been shown to be mitigated, management is in a much better position to not only develop a sound implementation strategy but to overcome the obstacles that otherwise would prevent them from achieving site-wide adoption within their organization.

Several of the TOC experts interviewed for this project referred me to a book by John P. Kotter as an excellent resource that could help me in getting CCPM adopted. In his book, *Leading Change*, Mr. Kotter identifies eight stages necessary for getting an organization to make a lasting change in the way it operates:

1. Establish a sense of urgency
2. Form a powerful guiding coalition
3. Create a vision
4. Communicate the vision
5. Empower others to act on the vision
6. Plan for and create short term wins
7. Consolidate improvements and produce more change
8. Institutionalize new approaches

Following these eight steps greatly improves the probability that an organizational change will be accepted by the environment and will have a long term impact. While each of the aforementioned stages is important, establishing a sense of urgency, forming a guiding coalition and knowing where to start CCPM implementation plays an extremely important role, especially in the early stages of adoption.

From these interviews, as well as discussions I have had with other members of the TOC community over the past two years, it appears that many of the organizations that have successfully adopted CCPM had a compelling reason for doing so. Some were losing customers or unable to win new business and, in some cases, were on the verge of going out of business. Still others were producing products and

services that had become irrelevant in the marketplace and were, therefore, facing a similar fate. Both of these situations provided these organizations an opportunity to create a sense of urgency and obtain employee buy-in and management support for trying something different. These organizations accepted that their current way of conducting business was insufficient and would lead to their demise unless they were open to changing their environment to support successful implementation of CCPM. Without this sense of urgency, gaining sufficient management and employee support for overcoming the cultural obstacles that challenge a CCPM environment is extremely difficult, prone to failure or, at best, will achieve only limited adoption by the organization.

My interviews revealed that a number of different approaches have been used both within and outside of my company for building a guiding coalition for CCPM adoption. These approaches range from soliciting support from Program, Project, and Functional Management organizations, to identifying Subject Matter Experts (SMEs) interested in spreading CCPM throughout the organization. While each of these approaches have been effective starting points, my interviews pointed out that in the end, support from all of these areas will be important for the CCPM implementation effort to be sustainable. However, one of the first things required for determining how best to spread CCPM is to understand who in the organization has the day to day authority to assign resources. In the case of a pure matrix organization where the Program controls the funding but the Functional organization controls the daily resource assignments, the functional organization will most likely

be the best place to begin establishing a CCPM implementation strategy. In the case of a loose matrix, or hybrid organization, where the Program controls both the funding and the resources, to get full benefit of CCPM, a resource sharing agreement between multiple programs may be necessary to facilitate a sharing of resources across the site's Programs.

2. CCPM Environment

As I have discovered from these interviews as well as my personal experience in attempting to implement CCPM, the characteristics of the environment have a direct influence on the degree to which CCPM can be adopted within an organization.

Everyone I interviewed for this project agreed that, for the most part, the degree to which CCPM will spread across an organization is largely determined by the level of active upper management support achieved. Figure 2-1, below, shows the relationship between the amount of upper management support and other factors that influence the degree of CCPM implementation in an organization.

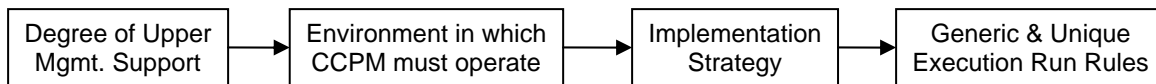


Figure 2-1, Impact of Strategy on Tactical and Execution Planning

If the highest level of management clearly understands what is in it for them and their organization by adopting CCPM, they are more likely to get actively involved in supporting CCPM. In these situations the benefits derived from implementing CCPM will be at their greatest. In such an environment, CCPM acts to align the organization's resources so that it will be in a position to share them across all Programs and functional departments and ensure that the most important goals for the organization are receiving sufficient support. It makes it possible for the organization to execute CCPM multi-projects, confident that the most important projects are being worked and that the most constrained resources are being put to the best use. An environment which enables CCPM to be adopted across the entire site provides the most resource leverage and, therefore, the most potential for the

organization. One of the interviewees I spoke with made a statement that puts this relationship and its impact in perspective. He stated that while organizations unable to achieve senior management support can still benefit from adopting CCPM, this lack of support leads to Undesirable Effects (UDEs) which limit the degree to which CCPM can positively impact the bottom line of the organization. A few of these UDEs are listed below:

- Managers and their employees are continually challenged by their environment which does not support CCPM, encouraging the team to return to their old habits.
- It is difficult to share resources across programs, departments, and teams.
- It is unclear what are the most constraining resources for the organization
- Resources are sub-optimized across the organization.
- CCPM implementation will most likely be limited to single or multi-functional projects.
- The full impact CCPM offers is not achievable by the organization.
- Special Execution Run Rules must be developed and implemented to mitigate the limitations imposed on CCPM by the environment.
- The rate of adoption is more heavily influenced by leaders in the organization that take it upon themselves to implement CCPM.
- The organization is continually at risk of losing support for CCPM when there are changes in organizational leadership.

Figure 2-2, below, graphically shows the relative impact to the organization if it is able to gain senior management support and execute a “Prototype Implementation Strategy” where organizational adoption is the intent, versus a pure project “Pilot Implementation Strategy”, whose intent is much more narrowly focused. The area under the curve in is an example of the relative monetary benefits that can be achieved from a “Prototype Implementation Strategy” as compared to the bars which represent the potential benefits from implementing a pure “Piloting Implementation Strategy”.

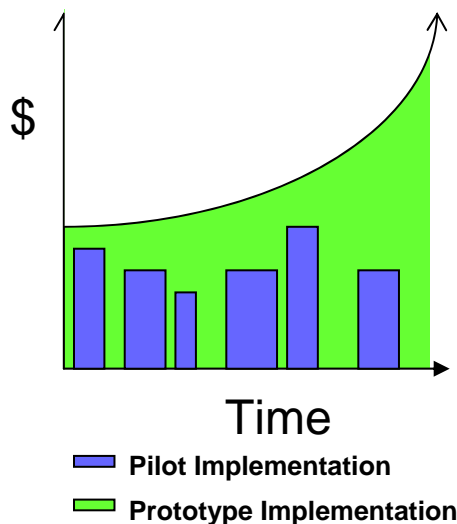


Figure 2-2, Pilot versus Prototype Implementation Strategy

The TOC professionals I interviewed from outside of my firm were very clear about the magnitude of the benefits an organization could achieve by taking a broader, prototyping approach versus a piloting one. In fact, one TOC expert warned me “not

to be seduced into doing endless pilots”. He mentioned that taking a piloting approach to implementing CCPM, while “safe” (politically), was not in the best, long term interest of the organization. While it was acknowledged that a “Piloting Implementation Strategy” produces some positive results for those departments that utilize CCPM, they also agreed that it can act to impede its growth and that the benefits attained were considerably less than what could have been achieved if the entire organization had implemented a “Prototyping Implementation Strategy”. When an organization is committed to adopting CCPM and uses prototypes to ensure the defined organizational risks associated with adopting CCPM are mitigated, the benefits are an order of magnitude higher.

After establishing the environment in which CCPM will operate, the next step is to design an implementation strategy that provides the best opportunity for CCPM to succeed and deliver the benefits it promises.

SECTION 3

Tactical Level Strategies

1. CCPM Implementation Strategies

Designing the implementation strategy for an organization is perhaps the most creative part of adopting CCPM. The implementation strategy is driven by a number of factors, the most influential one being the environment in which CCPM will operate. The implementation strategy should be designed to ensure that CCPM planning and execution processes may be achieved within its environment. By doing so, CCPM should be able to achieve its primary goal of finishing projects as soon as possible while simultaneously meeting the customer's quality requirements and staying within their cost constraints. Table 3-1 describes several example CCPM implementation strategies and describes the environment that influenced its design.

| Implementation Strategy | Environmental Limitations / Situation |
|--------------------------------------|---|
| Prototype + Rolling Project Adoption | Senior leadership actively supported adoption of CCPM, conducted a feasibility study and uncovered the potential risks to the organization. Prototype projects were used to verify that the risk mitigation strategies were effective. Once the prototypes were completed and the risks mitigated, the organization began educating and training the workforce. It began using CCPM for every new project that came into the organization until all of its projects were being managed using CCPM. |
| Piloting Approach | Support was not attained at the highest levels within the organization and was, therefore, limited to a piloting implementation approach. In this situation, the pilot team members vary from pilot to pilot. Once the pilots are completed, team members return to an environment that does not support CCPM. This leads to a slow and painful CCPM adoption process and one that is heavily influenced by the leadership at lower levels within the organization. The piloting approach continuously has CCPM in jeopardy of being dismissed by the organization. (If the organization's management insists on doing pilots, it is best to obtain up front specific requirements the pilots must satisfy for the organization to adopt CCPM on a much broader scale.) |
| Project Resource Segregation | This strategy is used in environments characterized as having both "steady" and "surge" work components. In this situation, resources are segregated into those that will handle the steady, routine projects and those that will handle special cases, or surges. In this way, those working on steady projects will not be interrupted and will, therefore, be able to achieve the full benefits of CCPM. During those times when there are fewer "surges" in the system, these resources work lower priority projects that do not have a precisely defined due date. |
| Focus on FAST! | This implementation strategy is best used in an environment characterized by a steady stream of small to medium sized projects. With this approach, senior managers are challenged to go as fast as possible and commit to completing a continually increasing number of projects each year using CCPM. For example, if a team completed eight CCPM projects last year, they may be challenged to commit to completing twelve this year. The focus with this strategy is on executing the projects as fast as possible. |

Table 3-1, Implementation Strategy Examples

The information contained in the table above represents real implementation strategies that were mentioned by the TOC professionals interviewed for this report.

Be aware that this list is by no means exhaustive, as most organizations using

CCPM have a customized implementation plan ideally suited to work as effectively as possible within their unique environment.

2. Risk Identification and Mitigation

The environment often imposes risks which would prevent the successful planning and/or execution of CCPM. Identifying potential risks that exist in the environment will have a direct effect on the design of the organization's CCPM implementation strategy. The mitigations put in place to address these risks can be reflected in the organization's Generic Execution Run Rules and an individual project's Unique Execution Run Rules.

Table 3-2, below, provides an example of project Unique Execution Run Rules along with the risk it is intended to mitigate.

| Risk | Unique Execution Run Rules |
|---|--|
| Unable to mitigate a problem for tasks whose duration is extremely short and could be completed before the next meeting | Employees working on tasks whose duration is shorter than 10 business days in duration, must provide the Project Engineer with a daily status (email, voicemail, etc.) including the following information: <ul style="list-style-type: none"> - Work activities remaining to satisfy the closure criteria - Estimated duration expected to finish this work - What could hold you up? |
| Being unaware of work restrictions could delay project completion | Thermal team members will work 4 hours straight each day M-F, without interruption when their project tasks are in work. |
| Prevent Interruptions and multi-tasking | To minimize the potential for interruptions all team members agree to do the following: <ul style="list-style-type: none"> - Not answer their office phone - Establish a backup to handle their regular work responsibilities during those periods when working on the CCPM project - Put a notification in their email referring others to their backup - Post a note outside their office requesting they not be disturbed |

Table 3-2, Unique Execution Run Rules Example

Table 3-2 provides an example of Generic Execution Run Rules that were compiled from my experience and from conversations with various TOC professionals.

| Risks | Generic Execution Run Rules (ERRs) |
|---|---|
| Unclear Priorities | Organizational project priorities are established based on the proximity of the due dates. Critical resource allocation decisions are based on the degree of buffer penetration, with projects in the red getting the highest priority. |
| Insufficient Management Action | Management action is required whenever: 1.) Project Buffer gets into the red, 2.) The Feeder Buffers are penetrated and 3.) Buffer Consumption Rate (BCR) exceeds an average of 1/3 over time for any task in work. |
| Adequate reporting & wasting Time | Prior to the Buffer Management Meeting, team members should provide the Project Engineer with the following information for tasks in work: <ul style="list-style-type: none"> - Work activities remaining to satisfy the closure criteria - Estimated duration expected to finish this work - What could hold you up? What help do you need? |
| Misunderstanding of input/output product requirements | Prior to starting the project the entrance and closure criteria for every task needs to be defined and verified by the engineer, their manager, and the recipient of the task deliverable being produced. |
| Insufficient Data Available to start the task | Task Readiness Review – Prior to starting the execution of each task in the project, verify that the inputs for a task are available and that the resource is ready to execute the task – “Full Kit” |
| Insufficient number of meetings to properly manage project | Project Engineers (PE) should conduct regular Buffer Management Meetings based on the average task duration estimate for the project. |
| Proper attendance at Buffer Management Meetings | Assigned employees with tasks currently in work, plus those that have been notified to get ready to start their work, should attend the PE’s Buffer Management Meeting. |
| Failure to provide the Project Engineer with Resource Buffer information could delay the project completion | Functional Managers need to provide the PE with the minimum advance work notification duration for each resource from their discipline assigned to work on the project. If this duration changes during the course of the project, the Functional Manager needs to notify the PE. |
| Failure to obtain clear commitment from FM’s could jeopardize ERRs | Functional Managers (FM) need to honor the General and Unique Execution Run Rules intended to protect / isolate their team members from bad multi-tasking, and other interruptions, etc. |
| Insufficient recovery time to complete the project on time | Whenever a project falls below 90% probability of on time delivery, a buffer recovery plan must be developed and provided to management along with the buffer report. |
| Failure to provide sufficient notification to the resource could delay the project completion | Project Engineers should stay in constant communication with the assigned employee and his Manager and provide them with: 1.) A general range of when their task is expected to start and, 2.) Formal notification (via email, etc.) of when their task will actually start in accordance with the minimum advance work notification period provided by Functional Manager. |
| Unnecessary rework and errors introduced into a product | A task cannot start until all of its required inputs have been received unless the activity proposing to start sooner does not depend on any of the inputs received at a later time for the task. |
| Multi-tasking, errors, efficiency | Once a task is started, work on it should not stop until it is complete or it needs to wait for another “external” input. |
| Failure to clearly communicate expectations could lead to multi-tasking | The PE, Functional Manager, and assigned employee need to work together to identify and define the Unique Execution Run Rules required to prevent bad multi-tasking and ensure successful execution of the project in accordance with the General and project Unique ERRs. |

Table 3-3, Generic Execution Run Rules Example

SECTION 4

Execution Level Strategies

1. Education and Training

Once management support has been established, the operational environment identified, and the specific implementation strategy defined, attention can then focus on educating and training the workforce to plan and execute CCPM. Interviews within my company revealed that it was best to separate the type and level of CCPM exposure into two categories: education and training. In this context, education refers to providing the team with an in depth understanding of the philosophy and behavior aspects of CCPM execution, whereas, training consists more of the “how to”, desk level instruction type information. Specifically, the depth and breadth of the education and training should vary depending upon the specific role and responsibility of the CCPM team member. While the Project Engineer and the Program and Functional Managers should be exposed to a deeper level of understanding of the philosophy behind CCPM, the team members charged with the daily execution of CCPM should have much more focus on specific execution activities and less on philosophy.

However, regardless of the depth of education and training provided, the first step is to, once again, be sure that the audience can identify their reason for wanting to implement CCPM. Similar to getting buy-in from senior management, the TOC experts all agreed that until an individual's reason for wanting to execute CCPM is

clearly understood, time will be wasted trying to “convince” and “sell” the person on the merits of this project management process. Even when support is obtained from senior management, CCPM adoption cannot be dictated. CCPM must be accepted by the workforce based on the benefits they expect to derive from its implementation. Table 4-1 below lists the most common benefits sited from various individuals and functions in the organization from executing CCPM.

| Function | Benefits Attributed To CCPM By Various Functions |
|---------------------------------------|--|
| Employees | <ul style="list-style-type: none"> – Increased job satisfaction – self managed teams (no micro-management); able to see contribution to the whole – Simplified reporting, focusing forward – Increased productivity with less stress (no multi-tasking) |
| Program Management / Project Engineer | <ul style="list-style-type: none"> – More control to execute project – Focus is on achieving a future state as opposed to reporting on the past. – Buffer Management Reports are a leading measure, supporting early identification of impending problems in time for effective corrective action to take effect – Easier to identify impending problems and mitigate them – Requires less time to manage – More responsibility for project execution and team management |
| Functional Management | <ul style="list-style-type: none"> – More available capacity with existing team members (25-50% more!) – More control over resources and team management – facilitates sharing resources across programs – Supports development and execution of a resource prioritization scheme – Ensures the most effective use of the manager’s most constrained resources – Fewer fire drills and better tools to manage them (surge capability) – Optimal use of resources – no justification required since employees are always working on the agreed to highest priority projects and tasks |
| Senior Management | <ul style="list-style-type: none"> – Provides positive, bottom-line results (typically 25-50% reduction in resources) – Ensures that their resources are being optimally used to support the goals of the organization – Enhances management’s ability to quickly identify project status and know where to provide help – Requires less effort to manage than typical project schedules – Finishing projects faster provides an opportunity to increase business volume and profitability – Because it requires a cultural change, CCPM provides barrier to entry and therefore the potential to obtain a long term competitive advantage |

Table 4-1, Benefits Attributed To CCPM by Various Functions

The training methods used, and their timing, are also important aspects to consider in educating the workforce on CCPM. As mentioned in Section 2, the TOC experts I interviewed believe that the most powerful method for training others involves a process whereby a person discovers for themselves the lesson that needs to be understood. Therefore, facilitation sessions involving hands on activities designed to teach a specific aspect of CCPM are an ideal education method. Appendices B-E provide four different hands-on educational simulations designed to show the flaws of traditional project management practices which are overcome by CCPM. In terms of timing, it is important not to overwhelm individuals just learning about CCPM with too much information. For that reason, the TOC experts determined that it is better to give “just-in-time” training to members of the team as they express a need, as more than likely they are then in a better position to use it.

2. Project Planning & Execution

Once the team has a general understanding of CCPM, one can begin educating and training the team on how to plan and execute a CCPM project. Unlike projects that are thrown together with little planning, CCPM projects require more rigorous planning, and reinforce good Project Management practices. Thorough CCPM planning is a critical part of ensuring that projects are completed on-time or ahead of schedule, are of the same or higher quality, and are delivered within the customer's budget requirements. The following lists the major CCPM planning activities.

- Establishing the team charter
- Establishing the Work Breakdown Structure
- Defining the roles, responsibilities, and authority for the project team members
- Defining the project network
- Identifying the planning resources required and obtaining their execution commitment
- Determining the resource notification buffer for each resource on the critical chain
- Obtaining the entry and exit criteria for each task in the project network
- Establishing the CCPM project schedule and resolving resource contention
- Establishing/modifying and monitoring the impact of any Generic and/or project Unique Execution Run Rules

Once the planning phase has ended, training the team on their specific responsibilities during project execution begins. Specifically, the team members need to be trained on the following aspects of CCPM execution:

- Fever Chart – Determining the Critical Chain and calculating the Project Buffer status
- Feeder Buffers and their role in protecting the Critical Chain
- Resource Buffers - How and when they are used
- When and how to report task status
 - Only three types of status exist for CCPM projects
 1. Task is finished
 2. Task has not started
 3. Task is in work. For tasks in work, employees need to provide answers to the following questions:
 - What work is remaining to complete the task?
 - How much time is required to finish this work?
 - What could potentially hold up this work from being completed?
- Project Buffer (PB) consumption and when to take action
- Buffer Consumption Rate (BCR) and when management action is required
- Using TOC's Five Focusing Steps to continually recover Project Buffer

With the team trained to understand the philosophy behind CCPM and their specific responsibilities during the execution process, the team should be trained on the

software tool(s) that they may be expected to use throughout the course of executing the project.

3. CCPM Software and Training

While it is more important to change the behaviors of how projects are executed than to worry about the specific software application which will be used, a couple of the TOC professionals I interviewed confirmed that the specific software application used can influence the rate of CCPM adoption. Specifically, it was mentioned that while most of the CCPM software packages are designed as an add-on software package to *Microsoft's Project* program, server based programs can facilitate organizational adoption. While stand-alone software packages cost less, the server based packages provide significantly more accessibility and versatility. In particular, it was mentioned that if the organization intends to conduct multi-projects, using a server based software package provides the most effective use of the organization's resources. Once a software package has been selected, the team members need to be trained on how to use it. This training will vary widely depending upon the specific CCPM application package available to the team. In the case of the stand-alone packages such as *ProChain*, *PS8* or *CCPM+*, the only person that needs training is the Project Engineer and, perhaps, their management. For more powerful software packages, such as *Concerto*, each team member will have to be trained on how to interface with the package to obtain and record their project task status information.

SECTION 5

The Problem with Projects

1. Conflict Cloud, Current Reality Tree and Undesirable Effects

The main difference between traditional project management techniques such as Critical Path Method (CPM) and Critical Chain Project Management, is managing the core project problem, variability. While CPM makes no attempt to deal with variability, the tools used to plan and execute CCPM are specifically designed to manage it. Traditional project management tools, such as CPM, are not capable of managing the variation that is inherent in all projects. There are three basic flaws, or assumptions, built into CPM project planning which makes changes necessary while precluding its ability to manage the associated task schedule variation:

- Task duration estimates are treated as deterministic once they are put in the schedule
- Task duration estimates have an unknown “pad” built into them
- Resource contention exists, thereby forcing resources to multi-task, which has the affect of expanding task durations and jeopardizing product quality

Successful projects satisfy three key objectives: 1.) Completing the project within cost, 2.) Meeting the product requirements, and 3.) Completing on time. Each of these three is a commitment, yet, due to the inability of project management tools to accommodate variation, project managers are often forced to compromise their original project commitment and accept that they will only be able to achieve two of the three original project objectives. Figure 5-1 is an Evaporating Cloud (EC) which

represents the Project Management Core Conflict. This figure shows the inherent conflict associated with planning and executing projects using traditional project management practices and tools. Specifically, this EC describes the conflicting choices that projects executed using traditional methods have because they are insufficient for managing common variations which are inherent in all projects.

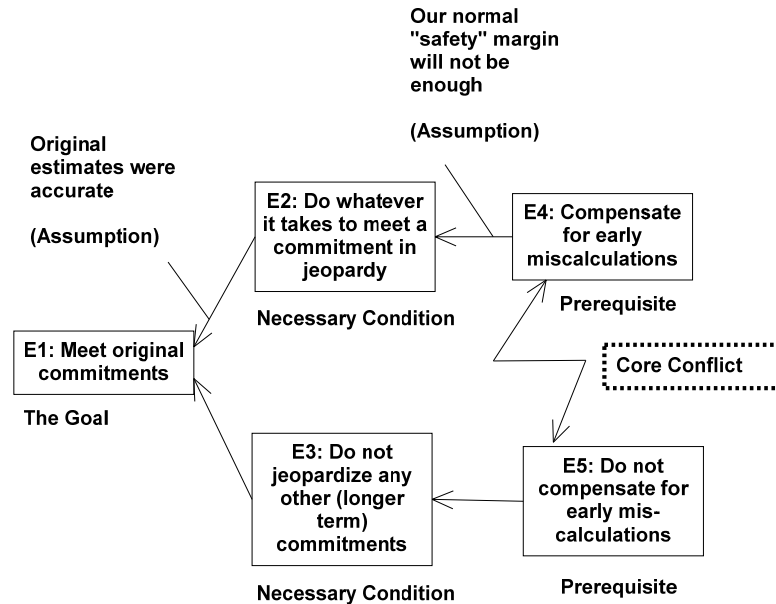


Figure 5-1, Project Management Core Conflict Cloud

The PM Core Conflict Cloud shown in Figure 5-1 leads to a number of undesirable effects (UDEs), which are then reflected in the environment as shown by the Current Reality Tree (Figures 5-2 through 5-4). Table 5-1, below, lists some of the most crippling UDE’s created by this conflict and their primary cause:

| Undesirable Effects | Primary Cause |
|---|---|
| <ul style="list-style-type: none"> • Availability of resources is impossible to judge • Sometimes workers are over-committed and must work “equal priority” tasks concurrently (multi-tasking) • Workers give worse case estimates | <ul style="list-style-type: none"> • Rewards/Measurements - Employees are measured on how busy they are, and whether they meet their “commitment” dates. |

Table 5-1, CRT Undesirable Effects and Primary Cause

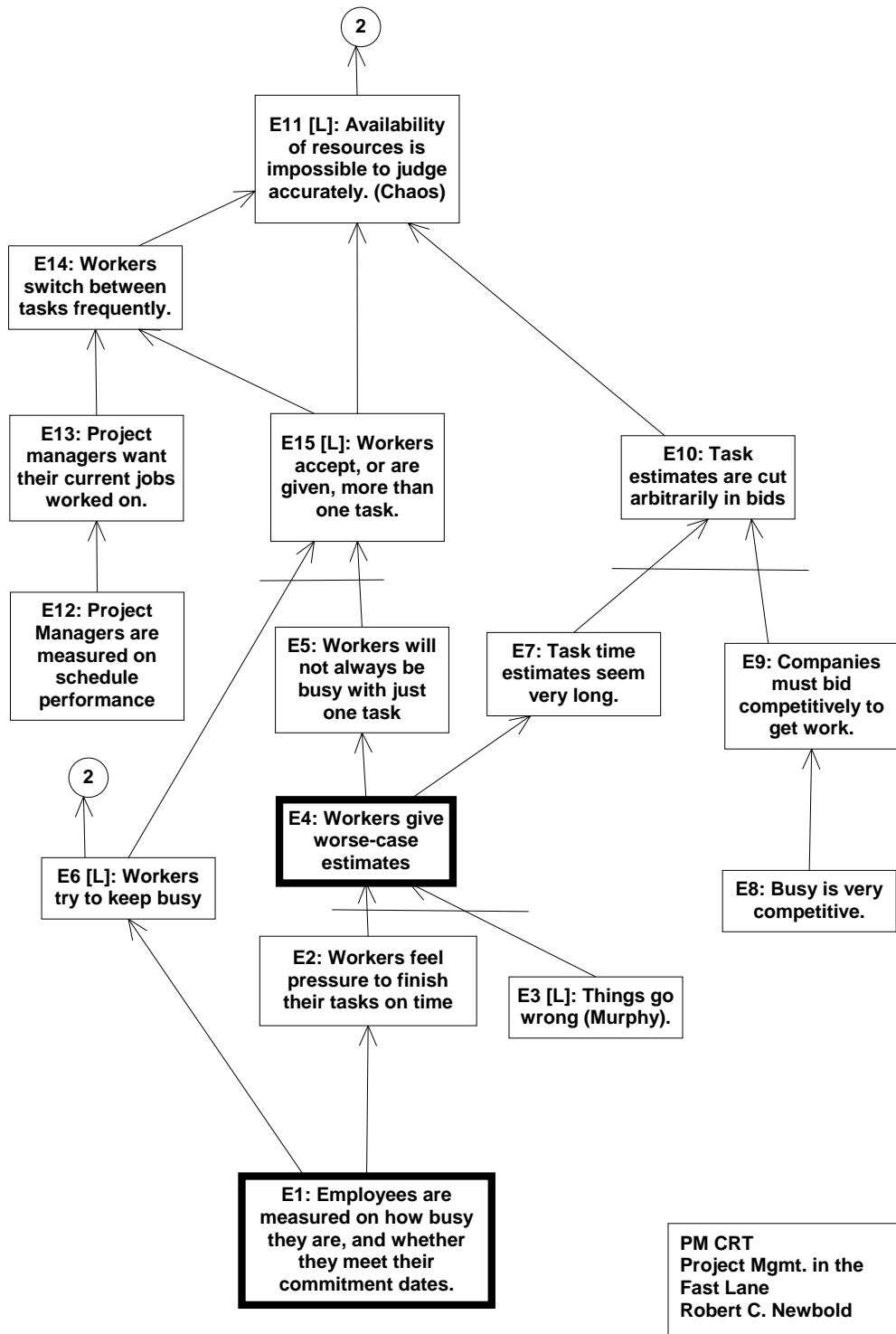


Figure 5-2, Projects Current Reality Tree, Page 1 of 3

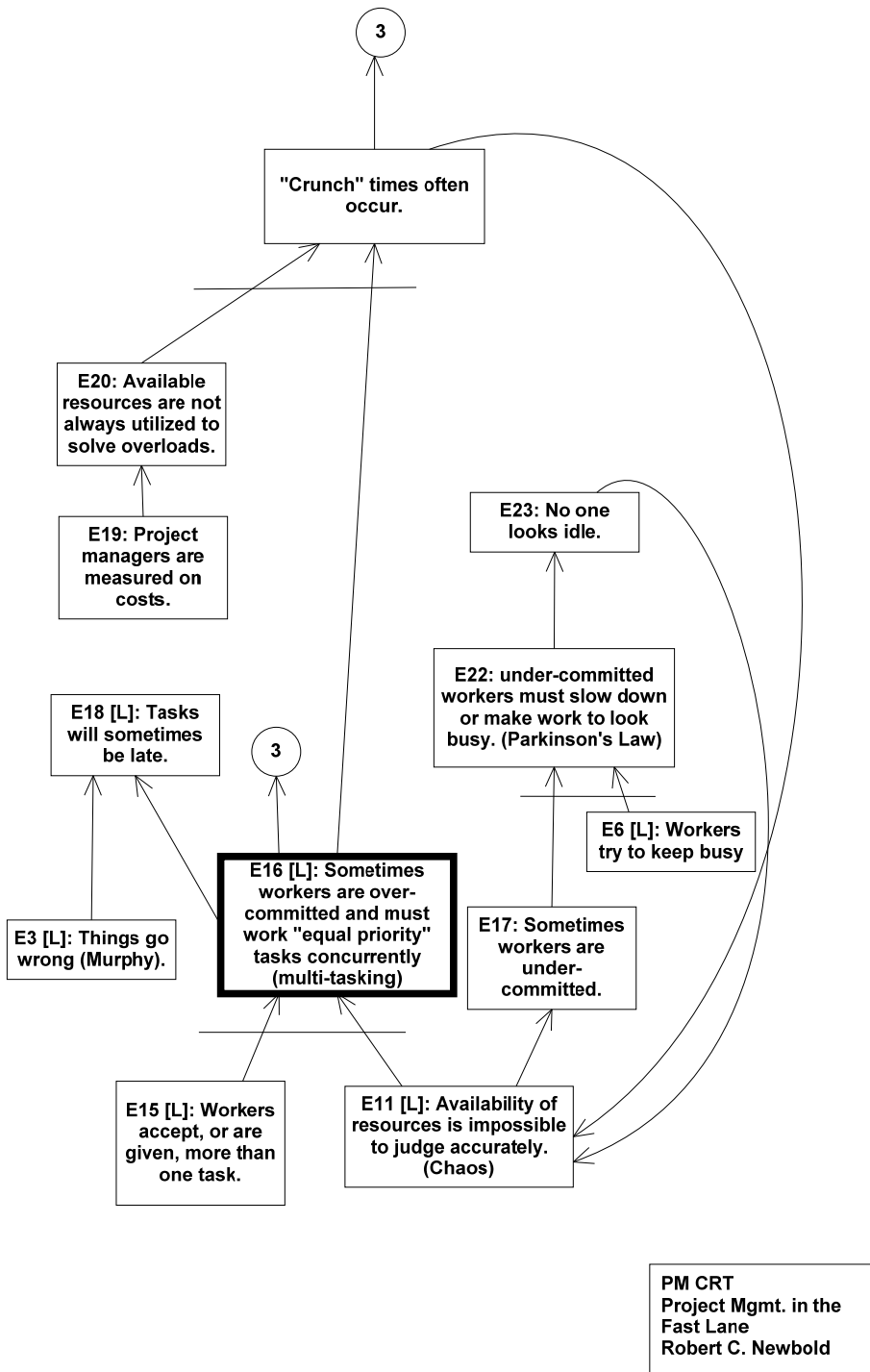


Figure 5-3, Projects Current Reality Tree, Page 2 of 3

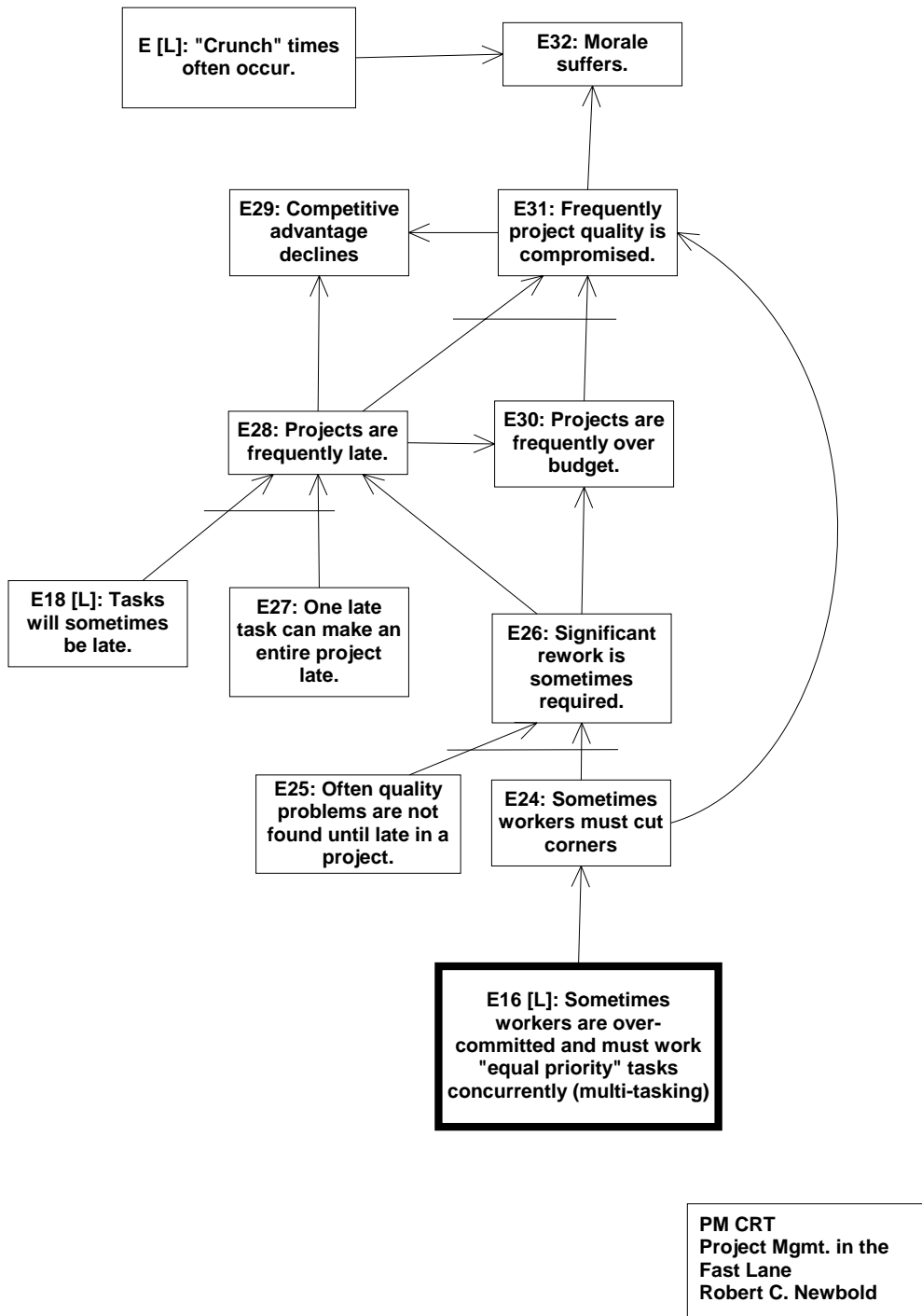


Figure 5-3, Projects Current Reality Tree, Page 3 of 3

2. **Activities to Facilitate an Understanding of CMP Project Undesirable Effects (UDEs)**

One of the most effective forms of education involves the use of hands on activities. Appendices B-E to this report include four activities which are intended to educate others on some inherent flaws/characteristics that surface as a result of using traditional project management practices which are mitigated by CCPM. Table 5-2, below, lists the undesirable effects caused by traditional project management practices and the specific activity used to demonstrate its impact on a project.

| Activity | UDE from Traditional PM Practices |
|-----------------------------|--|
| Aggregate Dice Game | Padding estimates |
| Nickel Game | Local vs. global estimates |
| Numbers, Letters and Shapes | Mental Multi-tasking |
| The Bead Game | Multi-tasking and worker overload |

Table 5-2, Activities and UDE's Addressed

SECTION 6

CONCLUSIONS

There are significant differences between obtaining approval to use Critical Chain Project Management for executing individual projects versus adopting it to achieve organizational resource alignment. In the first case, the organizational benefits achieved are significantly less and shorter lived compared to the synergistic environment created when CCPM is adopted across the enterprise and total organizational resource alignment is achieved.

When CCPM has active support from the highest levels of management within an organization, it possesses the greatest potential for success and reaping the full spectrum of benefits this method offers. In this situation, upper management provides an environment that supports CCPM and its execution, thereby freeing lower level managers and employees from the conflicts associated with not having a clear set of agreed to priorities. While CCPM implementation in this environment may initially require the establishment of Execution Run Rules for executing its projects, over time as the environment of the entire organization changes and embraces CCPM and its principles, it is anticipated they will become less of a necessity.

In those situations where CCPM is not supported by the highest levels of management, the general work environment will continually challenge those in the organization who are attempting to implement CCPM, encouraging them to fall back

into the old way of managing the resources of the organization. This situation requires proponents of CCPM to develop implementation strategies that include Execution Run Rules for managing their resources in an attempt to prevent bad multi-tasking and other behaviors which challenge sustained CCPM execution. This method's success will be limited to the extent that its advocates are able to sustain an environment conducive to CCPM execution. Until CCPM achieves sufficient active upper management support to change the culture of the organization, its survival will continually be in jeopardy and heavily dependent upon the supporting leadership in the organization.

Another necessary condition for successful adoption of CCPM is the willingness of all of its stakeholders. Individuals within the organization must be exposed to CCPM in a way that enables them to discover for themselves the benefits CCPM can provide for them and their organization. Some of the most effective education methods include storytelling, asking questions important to the particular stakeholder, and conducting hands on activities designed to teach some aspect of the CCPM processes.

SECTION 7

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SECTION 8

APPENDICES

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Appendix A – Representative Interview Questionnaire

The following is the list of questions that were discussed with TOC industry experts during the interviews conducted as part of this project.

- What are the key elements or necessary requirements/conditions that an organization needs to possess in order for it to adopt CCPM as the way of conducting all of its projects?
- What process/approach works best for creating these conditions and/or achieving these requirements?
- What has been your experience with conducting single CCPM projects in terms of gaining acceptance of CCPM in an organization?
- What are the key elements necessary for getting an organization to implement CCPM multi-projects?
- What is the best approach for getting an organization to adopt CCPM quickly?
- What are the benefits and drawbacks from using a Piloting Implementation Strategy to gain organizational adoption of CCPM?
- What is the most effective approach for educating the workforce on CCPM?
- What is the best way to develop a critical mass of people in the organization for expanding the use of CCPM?
- What role, if any, does a CCPM software package play in helping an organization adopt CCPM?

- What are the different implementation strategies you have been exposed to for implementing CCPM? What were the conditions that led to these implementation strategies?
- How important is it to get senior managers to conduct a feasibility study to determine the potential ROI of implementing CCPM?
- How important is it to have senior managers determine the risks and mitigation strategies for overcoming potential risks associated with implementing CCPM?
- What is the best approach for getting senior managers to fully support CCPM implementation?
- What is the biggest impact most organizations experience in adopting CCPM?
- CCPM requires managers to manage their resources differently. How would you describe exactly what that means to a manager operating in a CCPM environment?
- How would you describe the benefits of achieving multi-project CCPM implementation within an organization as compared to that of a single-project CCPM environment?
- How do you know that you really have active support from senior management?
- What are the biggest concerns senior managers have in adopting CCPM for executing all of their projects?

Appendix B – Aggregate Dice Game

Created by: Dr. James Holt

Primary Learning Objective is to get the team to appreciate the inherent variability involved in predicting task durations.

Learning Objectives:

- Function follows form – How punishment and rewards affect how people behave

Materials Needed:

- One dice per participant
- \$2/participant (each participant also needs \$1 each to play (or they can write an IOU) (Note that the money never really changes hands. The money is just for effect and to get them to think seriously.)
- White board or flip chart to record data taken from team during simulation.

Simulations assume 10 participants

Simulation #1 – Individual, Safe Estimates & Human Nature

Setup:

- Give each person a fair die
- Lay out ten \$1 bills on the table
- Say: I want each of you to predict what number you will roll, and for everyone that rolls a number that is equal to or less than what they predict, will get my \$1. However, if the number of your die exceeds your estimate, then I get your \$1.
- Expected Response: Everyone will choose 6 since that is the safest estimate/prediction
- Conduct a brief discussion on probability:
 - Ask: What is the average of the die? 3.5
 - Ask: What is probability of getting a 6 or less? 100%! Right!
 - Say: So, give me a fighting chance!!!!
 - Get everyone to agree to 5, letting them know that their probability of winning is 83.3% (5/6)
- Draw the axes to construct a histogram of the results from these simulations. The “Y” axes are the sum of the die rolled by the team members during each of the simulations.
- Write down everyone’s estimate on the whiteboard.
- Have each person roll their die and record the results of the number for each die on the whiteboard.
- Sum the results and put the total on the histogram.
- Repeat 5-6 times, recording on the table and histogram each time.

| Roll # | 1 | 2 | 3 | 4 | 5 | 6 | Total | Avg. |
|--------|---|---|---|---|---|---|-------|------|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| Total | | | | | | | | |

- Discuss the results:
 - How many people earned their \$1?
 - What was the average roll for each individual? 3.5??
 - What was the average of the prediction for the team?
 - What was the average of the results for the team?
 - Ask: How many people rolled a 1 or 2? 30%??
 - Say: What if everyone had rolled a 1 or a 2, how confident would you be that you could repeat this if I changed the wager such that you had to get a 2 or less in order to get my \$1?
 - Ask: What if I offered to change the wager and asked you to commit to rolling a 1 or a 2, what would you expect me to do? (Expect they would want me to increase how much I paid out since the probability of them losing goes up.)
 - Ask: So what's the point? And help drive out the following learning objectives:
 - Die have variability and cannot be predicted with any accuracy – so why try?
 - Each person was more willing to bet when they had a safety margin
 - The die has a lower and upper limit, 1 and 6, respectively

Simulation #2 – Team estimates; agreeing to more aggressive estimates

Setup:

- Change the situation: A new boss takes over and knows about probability and that less than $\frac{1}{2}$ of the time a 1-3 will be rolled and the other half a 4-6 will be rolled.
- Put \$2 on the table for each participant (\$20 total)
- Say: What if the new boss says that he will pay \$2 to each team member if the contract is completed within 50 days, but will penalize the team by taking \$1 from each person if it is not completed within 50 days? Would you be willing to take the contract?
- Have the team roll their die 5 more times and add their results in the table and histogram. The purpose is to convince the team that it is easy to commit to a target of 50.
- Say: But the new boss is “smart” and understands that the current project estimate of 50 has a high probability of being achieved, and instead insists on a more aggressive, 50/50 estimate. The boss states that everyone that rolls a 4, 5 or 6 must record that number, and those that record a 1, 2 or 3 must record a 3.
- Say: Looking at the table of data from Simulation #1, how many people would we expect to roll a 1, 2 or 3 vs. 4, 5, or 6? How likely would you be to take the contract as a team?
- Ask: How many would have to roll a 3 or less to get the profit?
- Say: If only one person rolls a 3 or less and everyone else rolls a 5, the team makes it! ($9 \times 5 + 3 = 48$, which is less than 50).
- Discuss whether or not those seem like pretty good odds. Review the histogram data.
- Ask: Would the team be willing to take this contract knowing that if the total of all of the dies was less than 50, everyone would get \$2, but if the team is over 50 each person would have to pay \$1?
- Say: The new boss has a new contract that requires be under 40 and will reward the team with \$4 each if the team meets this goal, while retaining the \$2 per person for being under 50.
- Ask: Should the boss commit the team to the new contract?
- Discussion: Review the histogram constructed as part of this exercise and has the team discover how often the sum of the team's die is under 50.
- State: What if the contract paid double again if the team could commit to 35 or less. What is the constraint? The answer should be that the constraint is now the safety margin, or buffer we imposed.
 - Discuss how the constraint in the system is what prevents the team from being more aggressive and that it needs to be removed.
 - Discuss how our safety margin was wasted

- Discussion:
 - What has changed as the result of this exercise, the people or the process?
 - The process changed as the team took more aggressive estimates
 - The management changed and eliminated penalties for those times when the target was not met.
 - Human behavior changed – When the focus moved away from the need to protect “my estimate” to achieving the goal, the safety was given up, providing the team an opportunity to commit to what originally appeared to be an aggressive goal.

Appendix C – Nickel Game

Created by: Dr. James Holt

Primary Learning Objective is to show participants the impact of local efficiency versus global efficiency

Learning Objectives:

- Help participants realize that when value is placed on local efficiency, global efficiency suffers.

Materials Needed:

- Ten nickels
- Flat surface / table

Setup:

- Take the ten nickels and place them all face up in front of the first participant

Instructions:

- Tell the participants that their job is to turn over each nickel and then record their time as soon as they have finished turning them all over and transferring them to the person to their right.
- As soon as the nickels have been transferred the participant records their time
- The process continues until all of the participants have completed turning over their nickels.
- The last person transfers the nickels into a cup, and the time is stopped.
- Spend a few minutes reviewing the individual efficiencies
- Repeat the simulation but this time tell the participants to do it with their primary hand hidden behind their back and instead of waiting until all coins are turned over before transferring the coins, that they should transfer each nickel to the person to their right as soon as they finish turning it.
- Record the time when each person finishes transferring the last coin, until all 10 nickels are back in the cup.
- Discuss the differences in the results.

Results:

- The participants should notice that their individual efficiencies each went down in the second versus the first simulation, but that all of the nickels were back in the cup much sooner.
- They should note that these results were achieved despite the handicap in the second simulation of having to put their primary hand behind their back.

Appendix D - Numbers, Letters and Shapes

Created by: Anonymous

Primary Learning Objective is to get participants to recognize that there is a cost in terms of lost time when individuals must mentally split their focus and switching between tasks.

Learning Objectives:

- Help participants recognize mental multi-tasking and its impact on increasing a task duration

Materials Needed:

- Piece of paper
- Pen or pencil
- Wall size whiteboard and marker
- Wall size time that can be used to record start and stop times

Setup:

- Take your piece of paper and write your name on the top
- Starting at the top of the page, set up three columns evenly spaced from right to left
 - Column #1 – Label “Letters”
 - Column #2 – Label “Symbols”
 - Column #3 – Label “Numbers”

Instructions:

- Ask the participants to provide an estimate based on working as fast as possible
- Tell the participants that they are to work from left to right
- Tell the participants that they need to record the time that they actually finish
- Count down and start the timer & record the results on a whiteboard
- Discuss the results
 - How well did their results match their estimate?
- Have the participants get a new piece of paper and label it as they did before
- Repeat the exercise except this time tell them they can go from top to bottom
- Count down and start the timer & record the results on a whiteboard
- Discuss the results
 - How did these results compare to the first attempt?
 - How does the quality differ between these two simulations?

Results:

- Students will record a time much shorter for the second simulation over the first one since they do not have to mentally switch to try and figure out the next symbol, etc.
- The quality of the information for the second will be neater than that of the first simulation
- This simulation clearly demonstrates that productivity (speed) and quality are negatively impacted when individuals are forced to switch their mental focus between tasks.

Appendix E – The Bead Game

Created by: Tony Rizzo

The Primary Learning Objective is to get participants to appreciate the impact bad multi-tasking (both within and between projects) can have on the workers, managers and their customers.

Learning Objectives:

- Participants recognize the negative impacts to both the project and its stakeholders caused from simultaneous execution of two projects while multi-tasking.
- Participants recognize the positive impacts to both the project and its stakeholders caused from sequenced execution of two projects without multi-tasking.

Materials Needed:

- 1 Red bowl and 1 red plate
- 1 Blue bowl and 1 blue plate
- 3 Plastic spoons
- 15 each of black, orange and white glass decorative stones that are flat on one side and semi-round on its opposite side
- Watch/clock with the ability to record seconds
- Pen or pencil
- Paper (to record when various portions of the activities start and stop)

Participants & Facilities Needed:

- 6 participants per team is ideal, with a minimum of 4 required
- Table capable of accommodating 4-6 adults

Setup:

- Each table of participants represents a team that will be challenged to complete two projects, a “red” project and a “blue” project based on following rules.
- Participants at the tables will each take on a different role on the team, as defined below:
 - Blue Project Manager – Wants the resources to work only on his/her project
 - Red Project Manager – Wants the resources to work only on his/her project
 - Resource 1 – Responsible for sorting the beads at the start of the process and integrating the beads back into the bowl at the end of the three phase process.
 - Resource 2 – Does the processing (sorting and flipping) of the orange and white beads
 - Resource 3 – Does the processing (sorting and flipping) of the black beads
 - Time Keeper – Must precisely record the start and stop of each of the projects

Instructions:

- Each project consists of three separate phases: Phase 1 is the Sorting phase where the beads are spooned from the bowl and placed on separate plates based on their color. Phase 2 is the Processing Phase where the beads are removed from the plates, placed flat side down on the table, flipped over so that their round side is face down on the table and then returned to their respective plates using a spoon. Phase 3 is the Integration Phase where the beads are removed from the plates and returned to the sorting bowl using a spoon.
- The game will be repeated three times, with each one demonstrating a different aspect of project execution:

- Run #1 – Single Project Execution
 - Run #2 – Simultaneous Project Execution. After three actions have been completed on the first project (red), start execution of the second (blue) project, continuously switching between both projects throughout their execution.
 - Run #3 – Sequenced Project Execution. For this execution, the red project has priority and a resource cannot start working on any task on the second project until their work on their task for the red project is complete. Seventy-five seconds after the start of the first (red) project, start the second (blue) project.
- Resource Rules – Run #1 (Single Project Execution – Multi-tasking within project)

- Resource 1 – When the project starts, this resource takes three orange beads and places them on one plate using their spoon, followed by taking three white beads and placing them on the second plate, and finally taking three black beads and putting them on the third plate. This process continues until all of the beads have been sorted onto the three plates.
- Resource 2 – This resource cannot start until all of the beads have been sorted by Resource 1 and places them on the plates. Then Resource 2 takes their spoon and removes three orange beads from the plate and puts them on the table, followed by three white beads. This process continues until all of the beads from the two plates have been placed on the table.

Once all of the beads are on the table, Resource 2 begins the flipping process. First Resource 2 makes sure the orange and white beads are flat side down, continually switching between orange and white beads after every three beads are checked. Once all of the orange and white beads are flat side down, Resource 2 then begins alternating between flipping 3 orange beads and placing them round side is down, and flipping 3 white beads until all of them have the round side on the table. Once all of the beads have completed the flipping process, Resource 2 begins putting the beads back on the plates using their spoon and a finger, again switching between 3 orange beads and 3 white beads until all of the beads are off the table and back onto their respective plates.

- Resource 3 – Similar to Resource 2, this resource cannot start until all of the beads have been sorted by Resource 1 and placed them on the plates. Then Resource 3 takes their spoon and makes sure all of the beads are flat side down. Once this has been verified, resource 3 flips each of the beads until all of them have their round side down. Finally, Resource 3 uses their spoon and a finger to place the black beads back on the plate.
- Resource 1 – Finishing the Project – Once all of the beads are back on the plates, Resource 1 can begin returning the beads to the sorting bowl. Resource 1 must alternate every three actions between placing the orange, white and black beads until they are all back in the bowl.
- Time Keeper – Must record the start and stop time for the project.

- Resource Rules – Run #2 (Simultaneous Projects with Equal Project Priority – Multi-tasking within and between projects)

- Resource 1 – When the red project starts, this resource takes three orange beads and places them on one plate using their spoon, followed by taking three white beads and placing them on the second plate, and finally taking three black beads and putting them on the third plate. This process continues until the second, blue, project is started.

Once the second project starts this resource must switch immediately to taking three orange beads and placing them on the first plate, then switch back to the red project and placing beads of the next color and placing them on the plate, before switching back to the blue project and placing three white beads on the second plate. This process continues with this resource continually switching between projects, and within each project switching between sorting the orange, white and black beads.

- Resource 2 – This resource cannot start until all of the beads have been sorted by Resource 1 and places them on the plates. Then starting with the red project, Resource 2 takes their spoon and removes three orange beads from the plate and puts them on the table, followed by three white beads. This process continues until the blue project starts. Once all of the beads for the blue project have completed the sorting phase, Resource 2 must start switching from processing red project beads to processing blue project beads.

Once the second (blue) project has started, after every three actions, Resource 2 must continually switch between the two projects until all of the beads for both projects have been processed. Once all of the beads for a given project are on the table, Resource 2 begins the flipping process. Switching between orange and white beads, Resource 2 makes sure the orange beads are flat side down, checking three at a time. Once all of the beads are flat side down, Resource 2 alternates between flipping 3 orange beads so that the round side is down, and flipping 3 white beads until all of them have the round side on the table. Once all of the beads have completed the flipping process, Resource 2 begins putting the beads back on the plates, again switching between 3 orange beads and 3 white beads until all of the beads are off the table and back onto their respective plates.

- Resource 3 – This resource cannot start until all of the beads have been sorted by Resource 1 and placed them on the plates. Then, starting with the red project Resource 3 uses their spoon to move the black beads from the plate and places them on the table. Once all of the black beads are on the table, Resource 3 makes sure all of the beads are flat side down. Once this has been verified, resource 3 flips each of the beads until all of them have their round side down. Finally, Resource 3 uses their spoon and a finger to place the black beads back on the plate.

As soon as all of the beads for the second (blue) project have been sorted, resource 3 must continually alternate its processing activities between processing the red and blue projects until each of these processes are complete for both projects.

- Resource 1 - Finishing the project – Once all of the beads for a particular project are on their plates, Resource 1 begins placing them back in the bowl. In doing this, Resource 1 first moves three orange beads and places them in the bowl, followed by three white beads and finally three black beads. As soon as the second (blue) project has all of their beads back on their plates, Resource 1 must begin alternating moving three beads from for the red project back into the bowl, to moving three

beads from the blue project back into its bowl. This process continues until all of the beads for both projects are back in their respective bowls.

- Time Keeper – Must record the start and stop time for the red and blue projects.
- **Resource Rules – Run #3 (Sequenced Projects with Red Project Priority – No Multi-tasking between projects)**
 - Resource 1 – When the red project starts, this resource takes three orange beads and places them on one plate using their spoon, followed by taking three white beads and placing them on the second plate, and finally taking three black beads and putting them on the third plate. This process continues until finished, after which Resource 1 may start sorting beads for the second (blue) project. Resource 1 must complete sorting the beads for the blue project before it can return to the red project to perform the Integration process.
 - Resource 2 – This resource cannot start until all of the beads have been sorted by Resource 1 and placed them on the plates for the red project. Resource 2 takes their spoon and removes three orange beads from the plate and puts them on the table, followed by three white beads and finally three black beads. This process continues until all of the orange and white beads have been processed. Resource 2 may only start working on the blue project after all of the beads for the red project have completed the processing stage.
 - Resource 3 – This resource cannot start until all of the beads have been sorted by Resource 1 and placed them on the plates. Resource 3 then takes their spoon and places the beads on the table making sure all of the beads are flat side down. Once this has been verified, resource 3 flips each of the beads until all of them have their round side down. Finally, Resource 3 using their spoon and one finger places the black beads back on the plate. Resource 3 cannot start working on the blue project until they have finished processing the black beads on the red project.
 - Resource 1 - Finishing the project – Once all of the beads for the red project are on their plates, Resource 1 begins placing them back in the bowl. In doing this, Resource 1 first moves three orange beads and places them in the bowl, followed by three white beads and finally three black beads. Resource 1 cannot start working on the blue project until it has completed the Integration process for the red project.
 - Time Keeper – Must record the start and stop time for the red and blue projects.
- **Discussion Questions:**
 - Have each of the resources discuss how it felt to conduct each of the three different runs
 - What was the impact of the resources having to switch between the two projects in Run #2?
 - What was the cost of adding an additional project in the multi-tasking environment?
 - What was the cost of adding an additional project when staggered with no multi-tasking, between Run #1 and Run #3?
 - Is it possible to finish projects earlier by starting them later?

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