Projects’ Analysis through CPM (Critical Path Method)

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Abstract

CPM, a technique for analyzing projects by determining the longest sequence of tasks (or the sequence of task with the least slack) through a project network

Organizations today are also increasingly using virtual project management teams. They are procuring expertise and materials from all corners of the world. Therefore, CPM and CCM process are even more complicated than in the past. These environments also create their own problems and bottleneck that have to be also considered when studying and process or situation. The need to increase profits and revenues has forced many establishments to try to optimize their resources. Every organization is created to serve and develop specific functions, procedures, and responsibilities. If these goals are achieved properly, the long-term stability of the organization is accomplished; and, in many cases, guaranteed. Increasing efficiency and productivity have always been key factors in implementing any change.

Key words: Management Engineering, Operations Management, Network Diagram Complexity Steps Team
Introduction

Managing and running organizations is an evolutionary process over the ages. Such processes have been undergoing many structural changes. Organizations have shifted from functional managed structures to project based organizational structures. Consequently, project management in organizations is becoming increasingly important. Indeed, it is critical for the success of the company. Most of the above mentioned process changes have occurred in the last three decades. Irrespective of the type of industry or the domain, the need for managerial and structural change is being observed.

This chapter aims to give an outline and scope of the study that will be undertaken in this work. Any study that can help organizations understand the factors that impact the management of resources in an organization is beneficial. The focus of this study is to understand and evaluate critical paths and critical chains in projects. Once again, this too is critical. The ability of the project team to identify these paths and formulate policies and procedures to measure and monitor the critical paths are paramount.

Background of the study

Project management is not a new concept for organizations or managers. The concepts and ideas behind effective project management are however constantly been undergoing modification and improvement. A Dupont engineer, Morgan R. Walker and a Remington-Rand computer expert, James E. Kelly, Jr, initially conceived the Critical Path Method (CPM). They created a unique way of representing the operations in the system. Their methods involved using “unique arrow filled diagrams or network methods” in 1957. (Archibald and Villoria, 1966, Korman, 2004) At approximately the same time, the U.S. Navy initiated a project called PERT (Program Evaluation Research Task) in order to provide naval management with an effective manner by which they could periodically evaluate the information of the new Fleet Ballistic Missile (FBM) program. The US Navy could obtain valid information of the progress of the project and also have a reasonable accurate projection of the completion of the project as desired. It is however, important to note, that PERT “deals only with the time constraints and does not include the quantity, quality and cost information desired in many projects; PERT should, therefore, be integrated with other methods of planning and control.” (Evarts, 1964)

While these two methods were revolutionary (for their times), the true impact of the concepts of CPM and PERT were often not as complete and holistic in their applicability. Theoretical and practical implementations of CPM and PERT also identified many areas of improvement over the years. The Theory of constraints in the 1980s followed by the Critical Chain complemented many of the concepts of these previous two tools.

Every organization is driven to succeed. An organization’s success or failure often depends on the clarity of its goals and objectives. It is often the management that defines these. (Morgan, 1998) In this environment therefore, it is important to identify the paths and options that managers and decision maker can utilize and refer to for complex and difficult issues. There are many related factors such as human perception and organizational culture and values that affect the implementation of these new models and tools. Organizations realizing that often project managers and team members are more involved with ‘fighting fires’ during the execution of the various tasks on the project completion are always open to the idea of finding new methods that can help projects become more streamlined and successful. The Pareto Principle or the ‘80:20 Rule’ provides a realistic picture of the time utilization most commonly arising. This principle states that 80% of most effort is spent handling just 20% of the most important factors of a task. In the modern work environment, lead-times and the times to (reach) market often determine the extent of profitability that can be obtained by any company. This is also true for construction projects, where the timely delivery of a building for residential use or commercial use can determine profits.
Purpose of this study

The main goal for any organization is to generate profits and revenue for the stakeholders. The task of determining how to run a lean and trim operation for any organization is complicated by issues such as manufacturing and operational lead times, replenishment cycles, unexpected surges in demand of a product, review frequency and the failure of establishing realistic target service levels by all involved in the operations. The idea of balancing flow (and not the capacity) throughout the plant is the considered the starting point for implementation of the Optimized Production Technology (OPT) program proposed by the Dr. Goldratt. The need to constantly generate profits for any organization forces management within the organization to evaluate and understand the internal and external factors that have the potential to create the most variance. Management of organizations is a complex process. In turn, organizations constantly seek methods and use tools that will help them understand their operations and optimize their operating processes for higher profits. This study by identifying the salient features of critical paths and critical chains hopes to offer the reader insight into the potential problem areas and methodologies or options that can be used to understand and evaluate the problem. In addition, this study also evaluates the similarities and differences in the concepts of the critical path and the critical chain.

This thesis aims to study the following topics

- Advantages and disadvantages of the Critical Path Method (CPM)
- Advantages and disadvantages of the Critical Chain Method (CCM)
- The impact of CPM and CCM on project management
- The complementing of the two methods and the ability to use both in conjunction for any project being implemented
- The issues of scheduling and the role of tracking and monitoring of the project’s progress from start to completion
- The effect of leadership, project team working and decision making styles on the CPM and the CCM used for projects

It is important to recognize however, that any reader realize that the topic and discussing of this topic is generic and individual organizations might require understanding the internal factors and culture in any organization wanting to implement and use this study. Evaluating the process is however, the first step in any improvement and change process in an organization. Scheduling, supply chain management and logistic planning in an organization is an important factor in successful achievement of any project.

Importance of this study

The mission and the goals defined in the organization are often the guiding factors in any strategy planning. Understanding the core competencies of the organization and supporting factors needed to achieve the objectives should be the bases of any knowledge management endeavor of the organization. Many external factors such as the competition in the industry for the same product or services and business strategies such as customer relationship management, supply chain management and logistics and planning all depend on the understanding of the critical path and critical chain that the project goes through from the start to the finish of the project. In the current marketplace, customers are becoming more aware of the choices available to them. Competition is more on a global scale than on a regional scale for any organization. Lead times are shorter. Product maturity period is also shorter. Obsolescence of products takes place within a shorter duration of time. Profitable periods are shrinking constantly. Most organizations are realizing that too many poor product launches can cost the company its reputation and consequently its profit margin. By
recognizing potential problems that can occur, decision-makers in project management situations can plan and prepare the person accordingly for the situation. Competition is very intense in modern day organizations. Companies are increasingly striving to differentiate their products and services in the market in order to gain higher profits and market-shares.

It is beyond the scope of any one study to completely investigate and study the impact of every variable that has created conditions that can disrupt a project from timely completion or launch. With this in mind, this study aims to identify the relationship between a few variables in CPM and CCM and answer some of the questions that typically arise, associated with these tool applications for projects.

**Scope of the study**

This thesis only investigates CPM and CCM methodologies in a very generalized format. This is without stressing the importance of these factors on any specific industry. For example, the project management needs of the construction industry can differ significantly from the software development industry. While both industries often use project teams for implementation of the task and completion of the project, the approaches to using CPM and CCM might not always run parallel in vision of execution. CPM and CCM will differ considerably even within the same industry based on the internal culture and the mission objectives of the organization in the industry. An ideal example is the construction industry where projects for residential complex construction will differ considerably from the construction of hazardous research facility although the variables involved in the process might be the same at a fundamental level such as procurement of material and hiring of labor are the same; but the expertise required for the construction will differ significantly from a residential to a hazardous facility construction.

Organizations today are also increasingly using virtual project management teams. They are procuring expertise and materials from all corners of the world. Therefore, CPM and CCM process are even more complicated than in the past. These environments also create their own problems and bottleneck that have to be also considered when studying and process or situation. The need to increase profits and revenues has forced many establishments to try to optimize their resources.

Every organization is created to serve and develop specific functions, procedures, and responsibilities. If these goals are achieved properly, the long-term stability of the organization is accomplished; and, in many cases, guaranteed. Increasing efficiency and productivity have always been key factors in implementing any change.

**Definition of terms**

The terms defined below are used at regular intervals in this thesis. Definitions of these terms are provided to ensure that the reader understands the context within which these terms are used and applied in this thesis. It is assumed that the reader will have some prior knowledge of the topic. As a result, only a few important terms are defined in this section. If additional terms are used, they will be defined when introduced in this thesis.

**Organization:** “A company, corporation, firm, enterprise or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration.” (GDRC, 2004)

**Project** is defined as “an endeavor to accomplish a specific objective through a unique set of interrelated tasks and the effective utilization of resources.” (Gido and Clements, 2003) Any project requires a plan of action in order to accomplish desired results. Thus, it requires “project management.”

**Critical Path** “In project management, a critical path is the sequence of project network terminal elements with the longest overall duration, determining the shortest time to complete the project.” (WordHistory, 2004)
Critical Path Method (CPM) “is a technique for analyzing projects by determining the longest sequence of tasks (or the sequence of task with the least slack) through a project network.” (Newbold, 1998) By concentrating on the most critical tasks it can be ensured that the project is on time and is keeping pace with the schedule set up.

Activity: A specific set of tasks or a single task that is required to be completed to ensure the completion of the project. All activities are related to each other and these relationships are called dependencies. (Archibald and Villoria, 1966)

Event: The result of completing one or more activity. (Meredith and Mantel, 1995) It is a discrete point in time on the project life span. An event does not consume the project’s time or resources.

Crash Time: represents the amount of time it would take to complete an activity if management wished to allocate additional resources to that activity.

Critical Chain: “The critical chain, in project management, is the sequence of both precedence- and resource-dependent terminal elements that prevents a project from being completed in a shorter time, given finite resources.” (Wikipedia, 2004)

Parkinson’s Law: Work expands to fill (and often exceed) the time allowed.

Murphy’s Law: Whatever can go wrong, will.

Project Buffer: Safety times that are introduced at the end of the critical chain prior to the due date that ensures that the project will be completed by the time due.

Feeding Buffers: safety time introduced after non-critical activities before they feed into the critical chain. This is done to ensure that the non-critical activities are always completed prior to their requirement on the critical chain.

Resource buffers “usually in the form of an advance warning, are placed whenever a resource has to perform an activity on the critical chain, and the previous critical chain activity is done by a different resource.” (Herroelen et al., 2002)

Theory of Constraints: A management Philosophy that “provides tools and concepts that can help make people and organizations more productive according to their goals.” (Newbold, 1998)

Bottleneck is defined as a resource whose capacity is less than or equal to the market demand. Bottleneck production should be on par with the market demand. The data that has to be collected from a bottleneck process has to be accurate.

Schedule is defined as “the plan for completion of a project based on a logical arrangement of activities, resources available (emphasis added), and imposed dates or funding budgets.” (AACE, 1990)

Optimized Production Technology (OPT) philosophy: “the sum of local optimums does not equal the global optimum.” Scheduling and prioritizing can help a manufacturing organization get their products to the market on time.

Globalization: “refers to the process of increasing social and cultural inter-connectedness, political interdependence, and economic, financial and market integrations. Globalization makes alliances an integral part of a firm’s strategy to better satisfy customers and to achieve sustainable competitive advantage.” (Thoumrungroje and Tansuhaj, 2004)

Stakeholders: is defined as, “Those who are affected by a development outcome or have an interest in a development outcome. Stakeholders include customers (including internal, intermediate, and ultimate customers) but can include more broadly all those who might be affected adversely, or indirectly, by an activity by the company.” (USAID, 2004) Stakeholders include employees, suppliers, creditors, customers, shareholders, local
communities and anyone else who is affected by the operations of the business.

Environment: is defined “as the sum of all external influences and forces acting upon an object”, the object can be either an individual or an organization. (Sewell, 1975) The traditional definition of an environment with reference to an organization is: “All the elements that lie beyond the boundary of the organization and have the potential to affect all or a part of the organization.” (Daft, 1997)

Organizational Culture: Schein classifies organizational culture into three distinct and different levels: 1) The most easy to observe and notice are the “artifacts”; the aspects like the dress and language used which are easy to discern but have their own symbolism; 2) at a stratum below artifacts are the “espoused values;” these are consciously identified strategies, goals and philosophies by the organization; 3) “the core, or essence, of culture is represented by the basic underlying assumptions and values, which are difficult to discern because they exist at a largely unconscious level, yet provide the key to understanding why things happen the way they do.” (Schein, 1992)

Organizational Structure: Structure is an entity (such as an organization) made up of elements or parts (such as people, resources, aspirations, market trends, levels of competence, reward systems, departmental mandates, and so on) that impact each other by the relationship they form. A structural relationship is one in which the various parts act upon each other, and consequently generate particular types of behavior. (Fritz, 1996) Organizational structure defines the command, control and feedback relationships among employees in an agency, and the information that they might require to complete their task.

**Limitations of the study**

This study is conducted using a secondary research method. While primary research can identify the trends and issues in any one organization or manufacturing sector, it does not provide a complete and comprehensive overview of every industry. The data that was evaluated for this study was obtained from books, magazine articles, journal articles and other peer reviewed periodicals and the Internet. This study reflects the common trends observed in the literature reviewed. The literature is largely based on the personal opinions and viewpoints of individuals who have worked extensively in this field. It constitutes an important aspect of the printed and published opinion. Adequate collaborative information was sought and reviewed to present as complete a picture of this topic as possible without concentrating extensively on any one topic or area of concerns. Sufficient collaborative information was verified for any given point of view prior to introducing the concept in this thesis.

There is an advantage to conducting secondary research as compared to primary research. Secondary research methods are cheaper. The time factor is not as critical as in primary research. There are however, some limitations to using secondary data. Primary data collection (surveys) on the other hand can reveal facts and features of any one industry in the manufacturing field more clearly and comprehensively. (Hutt and Speh, 1985) Primary research is expensive and also dependent on the quality of the information gathered. The integrity and the quality of the data can become questionably if the population from which the data has been collected is not adequately diversified and independent.

The term “project” can be applied to a wide variety of organizations and an even wider variety of situations. This study will focus on projects undertaken by organizations, both for-profit and non-profit organizations. There is no perfect project plan. Every plan has to be tweaked and modified at periodic intervals as the project process progresses. This study does not attempt to define a project plan to reduce risks and improve decision-making.
**Objective of study**

Projects are undertaken for a number of reasons. This study will identify some of these project variables that involve CPM and CCM. Consider the following examples: a project on continuous improvements, improving quality control, building a new facility for the company, designing the international space station, creating a new line of commercial aircrafts, a new highway or something as simple as designing new packaging material for an existing product line in the organization are just a few examples of projects that are undertaken by organization. It would be impossible to find a realistic definition of project management that did not have, “situation that needs attention,” “plan of action” and/or “implementation of the plan” in the wording of its text.

Most often, projects are generally over budget; they take longer than the projected time; or they simply have the wrong people selected for the tasks. Projects generally have a team assigned to them. Team effort and interaction is integral to the success of the project. The morale, skill and motivation of the team members in the project-team play an important role in the success of the project. There are many organizational variables such as the structure and systems that affect the decision-making styles. And as a consequence, so is the project management styles implemented by the project leader. Management styles have gone through faster evolutions in the past three decades than they have in the past three centuries. Information and technology available to modern day managers is much better and reliable than in the past. Overload of information however, can be prohibitive. There is the fear that the individual inspecting the records might not be able to filter through the noise in the data, which might preclude arriving at the correct conclusion. Planning and monitoring of the project are more complicated in today’s world of increasing outsourced operations.

No two projects are ever alike. This is true even if the starting variables for each are the same. Many of the internal and external environmental variables, economy of the region, the worker skill levels, cost of manufacturing and doing business and social changes affect project completion. (Kerzner, 1979) In project management methodology, failure to manage (and control) any one variable can result in the overall failure in completing of the project. Such projects, even when complete, result in decreased profits and lowered market acceptance. With markets becoming more global and organizations operating in more than one continent, the environment has become further complicated. Coordinating efforts and synchronizing tasks has become more critical in this environment. Virtual teams for projects are becoming more common; and the risks associated with these types of project teams are much higher.

**Literature survey**

This thesis identifies CPM and CCM. Both are used as management tools for ensuring that projects are on time and within the budget. In a project type of organization structure, most of the tasks undertaken are one of a kind or at least have some level of uniqueness attached to them. For example, a construction company might have different project teams for each building being constructed or facility or a pharmaceutical company might consider each product manufactured an individual project. Every project generally has a fixed time frame and budget for completion of associated tasks. A new facility construction has a budget. The time period allocated for the completion of the project. In many cases, the life span of a project-based organization is based on the duration of the project itself. Project management is as much an art as a science and involves more that just following preset directions.

It is important that every individuals associated with projects and especially, project management understand the basic notion that the reason why a project is conceived, planned and executed is to serve a final customer or user of the project’s outcomes. Projects without any end ownership is not sensible. (Martin, 1976, Pruitt, 1999) At the same time however, projects are becoming more complex. The risks involved in project planning
and design are also higher. Organizations can save money and resources by utilizing various simulation models to determine the effectiveness of the project. (Doloi and Jaafari, 2002) Planning is necessary for all projects. Simulating project needs at every stage of the project life cycle can help decision makers view the changes or modifications that might be needed in a plans. Research indicates that many of the problems experienced in projects are of a “management, organizational or behavioral nature” and rarely due to inadequacies in technique or skill. This is especially true of software related projects. (Hartman and Ashrafi, 2002)

The Resource based theory for managing projects is now becoming more acceptable. This theory postulates that the physical capital, human capital and organizational capital are all important variables in strategy planning. (Kotelnikov, 2004) Resources possessed by companies can be tangible (facility, equipment) or non-tangible (knowledge base, patents). A project feasibility analysis should be conducted at the initial stages and at periodic intervals during the project life. (Clifton and Fyffe, 1977) Projects should also have the internal financial flexibility to adjust to changes and modification in the plan and design during the duration of the project. (Farrell, 2002) Project financing and cost planning are important factors when finance planning for long-term projects, industrial projects and government projects.

It is important that management and decision maker in organizations using the project based model to realize that “projects are a highly distinctive form of work organization.” (Sauer et al., 2001) Individuals who work in this environment have to constantly perform at very high optimum levels, control structures have to be well defined, a fine balance between worker empowerment and management control has to be obtained and the organizational structure, culture and norms have to be sufficiently flexible to maintain constantly high energy levels within the organization. In this environment, management has to constantly monitor motivational levels and the workers’ dedication at every point in time during the project duration. Often, employees, by virtue of their skills, might function in more than one project and at different levels of responsibilities. All these conditions are very conducive in creating an environment where job stress might be very high.

Project strategies for any organization have to be employed based on the type of product, the life cycle of the product and the process involved in marketing of the product. Reporting and documentation of tasks is an important way of reviewing and understanding operations in any organization. All projects need a good method of documentation and evaluation of the tasks. These records can provide the bases for changes and improvements in the structure of the organization and the manner in which it does business. The ability of an organization to effectively document, archive and retire information in a timely manner determines its competitive edge. (Back and Moreau, 2001) The success of a project depends on “its efficiency, effectiveness, and timeliness.” (Jiang et al., 2002) Self-evaluation in any project is most likely the best method for evaluating the performance of the individual members of the project team and might help the members develops better skills and capabilities.

**The Critical Path Method (CPM)**

CPM as a management methodology has been used from the mid 50s. The main objective of the CPM implementation was to determine how best to reduce the time required to perform routine and repetitive tasks that are needed to support an organization. Initially this methodology was identified to conduct routine tasks such as plant overhaul, maintenance and construction. (Moder and Phillips, 1964) Critical path analysis is an extension of the bar chart. The CPM uses a work breakdown structure where all projects are divided into individual tasks or activities. For any project there is a sequence of events that have to be undertaken. Some tasks might be dependent on the completion of the previous tasks while other might be independent of the tasks ahead and can be undertaken at any given time. (Lowe, 1966) Job durations and completion times also differ significantly. CP analysis helps decision makers
The CP analysis is also a helpful way of identifying if there are alternate paths or plans that can be undertaken to reduce the interruption and hurdles that can arise during the execution of any task. Critical path analysis consists of three phases—Planning, Analysis, and Scheduling and Controlling. All three activities are interdependent. But they require individual attention at all different stages of the project. When the constraints in the project are of a purely technical nature the “critical tasks form a path (tasks linked by technological constraints) extending from the project start to the project completion, denominated critical path.” (Rivera and Duran, 2004) When the projects experience resource constraints critical tasks form a critical sequence.

While CPM methods are ideal to identify the nature of the tasks and the time and money that is involved at every stage of the process, it should be customized to suit the needs and goals of the organization and the project. Communication and information transfer issues are critical for successful completion of any project. By defining and creating standard operating procedures (SOP) for similar tasks performed at more frequent interval any organization can evaluate the progress and/or success of a project team with reference to these metrics. SOPs are not static entities; but rather, change and evolve based on the environment, the culture and norms and the type of product marketed in the region. It is important when using CPM that the project team has some historical information of the processes and the task and are able to reference this information during the planning and decision making process.

Control mechanisms in projects with respect to the alignment of the project outcomes with the plan initially proposed is important. As the person at the helm of a project, the project manager is responsible for the success or failure of the project as a whole. (Globerson and Zwikael, 2002) It is the responsibility of the project manager to look into the root cause of a problem if one exists and to identify the potential solutions that can be implemented. If the project manager himself or herself is the cause of the problem however, then arriving at an honest and appropriate solution might be impossible.

Realistically determining the sequence of events needed in the critical path is important. Nabors in the article ‘Considerations in planning and scheduling,’ identified that often in construction jobs the sequence of events are not always dependent. For example, the “electrical drawings did not have to be complete before foundations could be constructed, that all engineering did not have to be complete before construction could start.” (Nabors, 1994)

There are two methods by which the Critical Path can be identified. They are;

1. The forward pass. Here, CPM calculates the earliest time within which a project can be completed. “The date each activity is scheduled to begin is know as the “early start,” and the date that each activity is scheduled to end is called “early finish.” (Winter, 2003) In this method of critical path determination, the earliest possible date for starting of the project is identified and then the activities are lined up to identify the completion date.
The backward pass. Here, selecting the date when the organization wishes to complete the project or the last activity identifies CP. Time requirements are based on working backward from the final date desired for the last activity to the initial first activity. The dates identified in this method of CPM are called late start dates (for the starting of the first activity) and the late finish dates (for the last activity in the project).

Important for the CPM using either the forward pass or the backward pass is that the total time needed for completion of the project does not change but the dates when the project can be started might differ based on the approach used in the two methods. The selection of either the forward or the backward pass depends on the final desired results and the available documents and accurate data needed to determine the time for every activity on the network diagram. (Baram, 1994) Slack or float is defined as the time between the earliest starting time (using the forward pass method) and the latest starting time (using the backward pass method) used for identifying the critical path. “Total float (float) is the amount of time an activity can be delayed without delaying the overall project completion time.” (Winter, 2003)

Typically, the critical path has little or no slack or float built into the activities. Therefore, it can be stated that the activities on the critical path if subjected to extensive delays will make the project take longer to complete. If the earliest time that any activity can be started is the same as the latest time that the activity can be started then the timing of starting that activity is very important for the project. In addition, ensuring that the activity has all the necessary resources as and when required is paramount. CPM also connects the different functional factors of planning and scheduling with that of cost accounting and finance. In many situations, schedules are often created without considering the resource needed (the availability of the resources at the time it is required) and cost that is incurred in case these resources are not available. (Just and Murphy, 1994) Often, during the scheduling process in CPM it is assumed that the resources of labor, equipment and capital are unlimited when in reality this is not very true. The factor of resources can get even more complicated due to the interdependencies of the various resources on each other throughout the entire duration of the project.

It is important to note that every activity time identified in determining the critical path are done using a work calendar that is appropriate and relevant for the task at hand. In addition, with many projects the supply chain that spans the activities can lie on more than one continent complicating the task of identifying accurate start and finish dates that are appropriate for all the activities. The constraints in the system can also impact the float that is identified in the process. Resource constraints are often the most difficult to identify and evaluate especially if the same resource is required for more than one project. Projects are often managed very cost consciously during the initial stages of the project. As the project progresses, and if delays occur at various stages of the project, the cost of the project might be compromised to satisfy the time of completion of the project.

CPM identifies the two important variables of any project the time and the cost of the project. When CPM was initially introduced the techniques were best suited for well-defined projects with relatively small uncertainties in the execution of the project. During this time of CPM initial introduction markets were also very regional and localized and there were few dominant players in any given market. CPM was also well suited for activity-type network. PERT on the other hand was well suited for projects that had high degrees of uncertainty in the time and cost variables and was suited for projects that were dependent on activities that had to be conducted at various locations around the world.

There are external variables that can affect the CPM logic during the planning, scheduling and management process. “Priority changes, “across the board” budget cuts, negotiations with other agencies, evolving regulations, etc., can jointly or severally impact the CPM schedule, necessitating
frequent and potentially complex modifications.” (Knoke and Garza, 2003) Organizations also undergo various modifications with respect to the implementation of the management tools that they might use during the duration of the project. These management tools might affect the activities and the manner in which they are undertaken.

Organizational culture also impacts the CP analysis. It is normally observed that the work process “tends to accelerate as a deadline approaches.” (Cammarano, 1997) Most CPM account for buffer times in the activity duration. All the personnel involved in the project generally know this fact. Consequently work is often not always started when stated and any uncertainties in the activity process can seriously impact the completion date. Slippage on any one of the activities can result in the delay of the completion of the entire project. Corporate culture and values also have the ability to impact the CP analysis and management. An organization that has a track record of always completing projects on time is more likely to observe the start and finish dates when compared to an organization that has a poor project time completion record. The mentality that ‘it is okay for project to be late as long as they satisfy the requirements’ can also make the implementation of CPM methods fruitless.

The project manager’s attitude and mentality towards handling the activities in any project also can significantly affect the project. Often, stressing the fact that activities on paths that are not on the critical chain are on time can prevent a project manager from honestly evaluating the reasons for delays on the critical path. In some cases, incentives for completing a project on time can impact the manner and attitude of the individuals involved in the project. Some projects are subjected to penalty fees and negative ratings for the organization that is completing the project if it is not completed on time. These factors however, do offer some leeway for situations that are beyond the control of the organization such as damages to the facility caused by earthquakes, floods or hurricanes. Delays due to poor planning and scheduling of work are however penalized. In this environment, organizations work hard to ensure that the tasks are always on time.

The supply chain involved in the process of completion of the project also impacts critical paths. Supply chain in any organization is generally identified as a group of organizations or individual departments upstream (suppliers to the company) or downstream (moving the product produced by the company to the market or the next user), linked together to help move any product from the source to the supplier. (Trent, 2004) A facility construction, for example, has to rely on a structural contractor, an electrical contractor, plumbing and heating in addition to the ensuring that all the material needed for the construction is received on time for the process. When management philosophies such as Just-in-time (JIT) are used for the procurement of material delays from the suppliers can seriously impact the completion date of the project.

Critical analyses of every aspect of “value addition” to the product is needed along with non-value added activity that only increases the final cost of the product but does not provide enhancement or additional benefits to the product. Identifying the needs for each project and developing an appropriate request for proposal is very critical. (Gido and Clements, 2003) The WBS for any project identifies the major steps needed to undertake this project. “A good WBS simplifies the project by dividing the effort into manageable pieces.” (Rad and Cioffi, 2004) In addition, often, WBS offers members in the project an opportunity to define the standard operating procedure to handle issues such as estimating and costing, change management and work completion review. (Baar and Jacobson, 2004, Lamers, 2002) “It is vital to the success of any project that one unifying foundation be established for the project controls system.” (Hobb and Sheafer, 2003)

One of the main issues that most projects face is overshooting the initial budget and non-adherence to the time of launch. (Leemann, 2002) Scheduling and sequencing various tasks is also essential. It is essential that every task identified in the WBS be assigned an ID and an estimated start and finish date. It is important when creating the schedule that all the important variables
that have the potential to push back the opening date be verified. In addition, many construction projects are beginning to incorporate the CPM as mandatory requirements from the contractors and subcontractors undertaking the contract. (Baram, 1994)

Resource planning and tracking project schedules is very important for any project to be successful. Resource leveling is concept in project management that takes into account that the project might have many tasks that have to be completed concurrently for different projects at the same time. Consider an ideal example: a single individual who has the expertise to handle one task but many projects undertaken in the organization have to use the services of this individual at the same time. This same factor might also affect equipment (one machine has to perform the same task for 10 different projects at the same time) or capital resources (too many projects will stress the investment that can be potentially made for any one project) in the organization. If there is no leveling and no constraints of resources for the project then the manpower peaks early in the project. (Just and Murphy, 1994) Floats and critical paths breakdowns are generally as a result of the resource constraints and different methods of crashing the project can yield different results for the project.

**Advantages of using the Critical Path Method**

In the age where tools available to management are constantly changing and improving the ability of CPM to still command respect among the project teams and managers is testimony to the fact that this tools has proved very valuable and beneficial. Listed below are some of the major reasons why CPM is still used in organizations today

- CPM encourages managers and project members to graphically draw and identify various activities that need to be accomplished for project completion. This step encourages all members in the project team to evaluate and identify the requirements of the project in a critical and logical fashion. Activities that precede and follow other activities also require their own evaluation and analysis. This factor become very important if the activities are conducted at different physical location and the time and cost element is also subjected to external variables that have the potential to seriously impact the project time.
  - The network diagram also offers a prediction of the completion time of the project and can help in the planning and scheduling of the activities needed for the completion of the project.
  - Identifying the critical path for the project is the next stage of the analysis of the network diagram. In doing this, the management of the project has a reasonable estimate of the potential problems that might occur and the activities at which these problems might occur. In many cases the critical path also determines the allocation of resources. The interpretation of the network diagram also ensures that the same resource is not allocated for the same period of time.
  - CPM also encourages a disciplined and logical approach to planning, scheduling and managing a project over a long period of time. Often, the root cause of many project overruns is the failure to identify the factors that have the potential to seriously impact the project. By forcing individuals in the project team to identify activities, attention to details can be achieved. In turn, this helps a true and much more accurate picture of the processes that need to be set up for the project and the time and cost that is needed for every stage.
  - A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the organization is also an important task to be undertaken at this point. In an organization, SWOT analysis should be undertaken at the corporate level and at the department level. Carrying out an analysis using the SWOT framework will reveal changes that can be accomplished; as opposed to those changes that appear to be optimal solutions initially
but would not be as effective in the long run. Being realistic when evaluating variables affecting the organization’s function and its future is very important in order to make the SWOT analysis exercise effective. Areas of improvements, problems faced, badly executed decisions and avoidable choices made have to be evaluated. The opportunities and the areas where the company can grow and improve should also be evaluated along with real and perceived threats that face the company. Identifying methods for creating an effective team performance across job-function strata in the organization; and analyzing the methods for assigning responsibilities and duties is important.

- Optimization of the time-cost relationship in project management is also possible using the CPM as managers can visually identify the activities that can pose a problem if not managed and monitored effectively over a period of time. In many situations the cost structures in organizations are still based on functional structures, although project structured organization might have different form of costing used for different projects. The task of identifying the accurate cost of the project is not easy and is not universal to all projects or all companies. Developing time-cost relationships for projects requires that project managers are able to identify root cause of the problems that are impacting the time and the cost variable.

- Based on the time-cost variables, the project can be tweaked to best satisfy the goals and aims of the organization. For example, if a project team is able to identify that they need more time if the project has to be within a certain budget or vice versa this fact is clear right from the start of the project. While it is presumptuous to aver that every factors affecting activities can be identified at the initial stages, a large portion of the factors and variables can be understood and the risks and uncertainties associated with each are known prior to starting of the project.

- Tracking the CPM is also helpful. Managers can identify areas where attention needs to be focused. Critical paths do not remain static for the life of the project; rather there is a very high chance that the CP might changes due to internal and external factors affecting the organization. The 9/11 attacks, for example, shutdown every major port. CP that estimated for example seven days for delivery of raw material from out of the U.S. had to change their critical paths. In some cases, the internal factors such as union issues and sudden equipment failure might also impact the critical path.

- Scheduling of activities is possible. The CPM identifies the entire chain of activities. Often, during the initials stages of the project the number of activities and the cost requirements might be high; but as the project progresses the activities might sort themselves out into routine or critical. Project managers, instead of tacking the entire issue, can focus their attention to groups of activities that are immediate and have the ability to impact the next downstream activity.

- The CPM also identifies slack and float time in the project. Thus, project managers can identify when resources can be reallocated to different activities and the shifting and moving of activities to best optimize the utilization of the resources.

- Critical paths are also updated periodically for any project and offer the project manager and members a visual representation of the completion of various stages of the project and easily identify problem areas where further attention might be required.

- In many large projects, there can be more than one critical path in the network diagram mapped out. When such a situation arises, CPM can help managers identify suitable plan of actions to handle these multiple critical paths.

- CPM has been widely used by a variety of organizations in almost all industries with great success. CMP can also help estimate the project duration and this information can
be used to minimized the sum of direct and indirect costs involved in the project planning and scheduling

- CPM offers organizations a form of documentation that they can reuse for similar projects that they might undertake in the future. Documenting various activities and the root causes of the problems can help future-project manager avoid similar pitfalls. In addition, documentation can provide valuable data for estimation of time requirements and cost factors, as opposed to managers using estimations and guesses of the cost.
- “Critical Path Analysis formally identifies tasks which must be completed on time for the whole project to be completed on time, and also identifies which tasks can be delayed for a while if resource needs to be reallocated to catch up on missed tasks.” (MindTools, 2004) The CPM can identify the paths that can be taken to accelerate a project to be completed prior to its due date or identify the shortest possible time or the least possible cost that is needed to complete a task.
- CPM methods are based on deterministic models and the estimation of time activities are based on historical data maintained within the organization or data obtained from external sources (like request for proposals return information)

Disadvantages of Critical Path method

CPM has a number of advantages and it has been able to provide companies using it a yardstick and a reasonable estimate of the time needed for the completion of the project. The main disadvantages of the critical path method are listed below. Many disadvantages are as a result of the technical and conceptual factors involved in the CP analysis (CPA) process

- The CPA process can become complicated as the scope and extent of the project increases. Too many interconnecting activities can result in the network diagram becoming very complicated. The risk of making a mistake in calculation of the critical chain becomes very high as the number of activities increase.
- The CPA depends on the fundamental concept that the managers and personnel involved in the project team are well versed with the various activities. “Unfortunately, practical experience has shown that the principal assumption underlying CPM techniques, i.e., the project team’s ability to reasonably predict the scope, schedule, and cost of each project, is frequently far beyond control.” (Knoke and Garza, 2003)
- The task of understanding the needs of the critical path get more complicated when there is more than one critical path in the project. In many situations, these paths might be parallel and feed into a common node in the network diagram. It becomes difficult in these situations to identify the best utilization of technology and resources for the critical paths.
- In many cases, as the project progresses, the critical paths might change and evolve and past critical paths may no longer be valid and new CP have to be identified for the project at regular intervals. This implies that the project manager and project member have to constantly review the network diagram initially created and identify the shifting and movement of the critical path over time.
- “The use of total float as a measure for assigning activities to their representative paths can become problematic when analyzing as built schedules. CPM is unable to calculate total float on an as built schedule in which estimated dates have been replaced by actual dates.” (Peters, 2003)
- As critical paths and floats change the scheduling of personnel also changes. Reallocation of personnel is often very tricky as the individual might be working on more than one project at a time and if the services of the individual are required on more than one critical path the identification and distribution of the labor time can cause overloading of the personnel—creating a stressed out worker.
- Very often, critical paths are not easy to identify especially if the project is unique and has never
been undertaken by the organization in the past. The ability to provide estimates of time and cost for every activity in a tradition CPM process depends on historical data maintained by the company. In the absence of this data, decision makers are forced to speculate and assume time and cost requirements for the projects.

- Traditionally, any good CPA requires that the process is understood and evaluated using the forward and the backward pass to determine slack or float times. In reality, however, the time constraints often result in decision makers using only one method to find the time and cost requirements. As a safety, however, these individuals often 'crash' the project during the planning stage and determine the maximum cost that would be needed to complete a project. During estimation, they use a midway cost value for the project thereby intentionally hiking the cost of the project. This mentality can cost the often overestimation of time and cost encourages the workers to postpone the start date of any activity on the network diagram to the last possible start data. Any serious variances consequently result in the slippage of the project completion date thereby increasing the cost of the project as the project is then crashed from that point onwards.

- CPA and network diagrams are highly dependent of information technology and computer software. The cost of set up of software systems in the organization can have high initial cost. Maintaining the software also requires expertise and monitoring that can quickly become very expensive if the organization does not have in house capabilities for this task.

- Planning and strategizing for the project based on the final expectation and the internal culture and values of the organization is also very important.

- Organizations are also becoming increasingly global and political. Social and economical instability in one region of the world can seriously impact production in another. If organizations depend on activities that span the globe the task of coordinating the planning and scheduling of activities at various location can get further complicated.

- In order to improve profits, it is necessary for companies to streamline their operations to maintain their position in a constantly evolving product market. To do this, companies are forced to improve their manufacturing performance and reduce the operations cost. Managers at every level are forced to evaluate their processes from suppliers to the end user. A part of the analyses also extended from the company’s supply chain and the individual suppliers. Companies are going from a multitude of suppliers to a few trusted and reliable ones in an effort to track quality and keep down costs. However, this process also is fraught with perils if the supplier is unreliable and sudden unforeseeable factors impact the activity time.

- Although the CPM method is very valuable in the extent of details that it provides, modifying the system constantly can be cumbersome especially if it involves reallocation of resources and time.

- In spite of the widespread use of CPM in organization the manner in which it is used can differ significantly. Organizations that have a strong culture of timely completion might be utilizing the methodology in a more appropriate manner when compared to companies that use CPM only partially for planning and scheduling.

- Knowledge management of data is important. Defining knowledge is never easy. Knowledge and information are different although they are often assumed to be the same. There are important distinctions between data, information and knowledge. Data are the raw facts collected by observation or monitoring. When data are filtered out to identify trends and organized it converts to information and when this information is used in the operation, planning and strategy it is converted to knowledge. (Yahya and Goh, 2002) Information and knowledge get transmitted through an organization through
communication networks. CPM depends on the efficiency of these networks.

- Knowledge is defined as “information laden with experience, truth, judgment, intuition and values; a unique combination that allows individuals and organizations to assess new situations and manage change.” The main purpose of any knowledge management strategy is to “reduce errors, create less work, provides more independence in time and space for knowledge workers, generates fewer questions, produces better decisions, reinvents fewer wheels, advances customer relations, improves service, and develops profitability.” (Karlsen and Gottschalk, 2004) In project environments, using this knowledge as and when needed is critical.

- In many recent cases, fear of litigation and delay claims based on the CPA used by companies is also being observed. Lawyers are using experts to investigate the CPA that were undertaken by contractors for projects and identifying the reasons for project delays. (Schumacher, 1997) When penalties and fines are imposed for late completion the CPM used by contractors can be subjected to scrutiny and might be responsible for organizations loosing a case.

- Sometimes projects use different calendars for the scheduling and planning and this can cause more complications. “There are numerous types of calendars used in construction projects. The following examples are most frequently found in construction schedules. Construction projects typically run five-days-a-week (40-hours/week) calendar. Besides, non-working Saturdays and Sundays, usually holidays are also non-working days.” (Scavino, 2003) Some contractors however, can also use the six-day calendar or a seven-day calendar as needed. Scheduling a project using the combination of calendars can create confusion if the CPM if the individual analyzing the CP is not careful about evaluating the type of calendar used for the different activities in the network diagram. This issue gets only more complicated if CP changes constantly.

- Many projects are generally long duration (3-5 years) in nature. It is often observed that the personnel involved in the project also changes as the project evolves. Many of the initial members might have left the company or transferred to other departments or even retired and the new member might not be as well versed with the initial concepts and brainstorming that went into the creation of the network diagram. Changes and modification made over the period of time on the network diagram can also be difficult to track if a good method of documentation of the change is not made. Often, poor documentation is the cause of the same mistakes being repeated over a second time.

- CPA also does not take into account the learning curve for new members on the project or for activities that are new and unique to the project. (Badiru, 1995) Using past information of learning curves can help project managers estimate time variations in case a new employee is put on the task or a new process is required for any activity to be completed. CPM does not traditionally consider this as an important variable for allocation of time or resources.

The Critical chain and understanding the Theory of Constraints

Goldratt introduced the concepts of critical chain for project management. He defined the critical chain as “the longest chain of dependent steps. The dependencies between steps can be a
result of a path or a result of a common resource’” (Goldratt, 1997) “The critical chain thus refers to a combination of the critical path and the scarce resources that together constitute the constraints that need to be managed.” (Elton and Roe, 1998) The figure indicates the concept in greater graphic detail. (Sciforma, 2004) The critical chain methodology incorporates the benefits of the CPM and PERT methodologies with the human and behavioral impact on project management in an organization. The Human element was not a major concern in the CPM and PERT and human tendencies were not considered critical in the completion of the tasks. The book Critical Chain applied the TOC to the task of project management. (Schuyler, 2002) Where in the past TOC concentrated only on manufacturing and production, Goldratt with this book was able to use the main concepts of TOC to improve the productivity of the project management process. “The critical chain yields the expected project completion date.” (Raz et al., 2003)

There are five key factors incorporated in the critical chain method that has the potential to significantly improve the project performance. They are:

1. “Use of a synchronization mechanism to stagger work.
2. Creation of project networks that are true structures of dependency.
3. Creation of schedules that place safety strategically to protect against variability along the longest path of task and resource dependencies.
4. More effective work and management behaviors
5. Project management and resource assignment based on relative depletion of project safety” (CriticalChainLtd, 2003b)

The critical chain refines and improves upon the critical path method used in project management. Very often, problems common to almost all projects are budget overruns, time overruns and the compromises in the quality and the performance of the product. In many project situations, decision managers and project manager are far removed from the actual task function and as a consequence have to either rely on dependable information or assume a lot of the information. Top management also forces options (decreasing the time to complete the project, cutting cost of the project or reducing the resources available for the project) on the project teams that are unrealistic.

Every business has measurements. These are a result of the market economy. (Drucker, 1974) One of the key performance measurements used (more often) is the Economic Value Added (EVA). Here, management closely monitors if the operations and the strategies are generating profits for the organization. (Fletcher and Smith, 2004) Constant self-assessment within an organization can help in the implementation of improvements in market-share and profitability using the EVA. (Evans, 2001) An organization that uses EVA should not attempt to use any accounting change to evaluate the EVA. Rather, the evaluation should be performed using realistic and accurate data. The ability of any organization to identify the fit between activity that would be performed and the strategy that would be employed by the company can help that organization stay focused and dedicated. (Porter, 1996) Hard evidence in terms of return on investment (ROI), inventory turnover rates and better-cost structure impacts to colleagues, customers and stockholders should be used constantly to ensure that the metrics used for EVA are appropriate for the situation. (Knights and Morgan, 1991)

In many modern organizations, the capital investment made is subjected to a lot of scrutiny and organizations prefer to wait for the last possible day to invest the monetary resources. “Project management must reconcile two conflicting aspects of projects -- the increasingly important need for speed in project delivery and the equally important need for reliability in delivering the project as promised.” (Patrick, 1999)

Deming realized the effect of variance on the production process. (Deming, 1950) There are two types of occurrences in manufacturing operations: a dependent event in which the
progress is made from one process or machine to the next in a sequence that is predetermined; the second is a statistical fluctuation that occurs due to the process itself. Statistical fluctuations do exist in any operation and the ability to smooth out the variance can be achieved only within a certain range of the fluctuations. (DeVor et al., 1992) The TOC model postulated by Goldratt duplicates the requirements of Statistical Process Control (SPC). (Goldratt and Cox, 1993) TOC forced companies to look within their process at the constraints and bottlenecks that were hindrances in the generation of maximum profit. The theory of constraints looked for the critical path in any process. The machine with the slowest output, would determine the constraint. Labor and employee requirement is an important intrinsic factor that affects the internal environment in an organization in the TQM model. The TOC model enhances the TQM model in this arena.

Goldratt stated that a production facility is only as fast as the slowest process in the critical chain of the manufacturing. Detailed understanding of the logistics involved in getting the product from suppliers to the customers, both internal and external is important. (Ayers, 2001) TOC postulates that a seamless, flawless and well-connected supply chain can help keep manufacturing-costs down. TOC looks at the cost effectiveness of running an operation and proposes that manufacturing should not create waste on the sole basis that waste is useless and therefore cost the company money. TOC postulates that many constraints could be eliminated or reduced by proper design and scheduling. There will however, always be an operation on the critical path, which will determine the rate of manufacture of a production plant. For this process to be successful, upper level managers have to be actively involved with the shop floor workers in determining the critical path. Critical paths will change and evolve with every change that is made to the flow of material in the plant.

Analysis of the setup times in relation to the cost of manufacturing in a batch was also considered important by conventional standards for all resources bottleneck and non-bottlenecks before the launch of Goldratt’s TOC model. This setup time however, is only considered really significant on bottleneck operations in the Goldratt model. An hour saved at a bottleneck is of very significant importance and will determine the bottom-line profits for an organization. Bottlenecks govern both throughput and inventories in a manufacturing system. An hour lost in a bottleneck is an hour lost in the total system. Consequently, an hour saved at a bottleneck operation is an hour saved in the entire process. The cost incurred due to the loss of an hour at the bottleneck is in fact the cost of an hour in the entire system. (Goldratt, 1990)

An attempt to run organization in a lean manner and an awareness of the importance of continuous improvement is growing in manufacturing based organizations. Creating a constancy of purpose towards improvement and strategy planning based on long-term goals of the organization can help enlighten those involved with the organization to problems that they face or might face. In the book, “The Goal: A process of ongoing improvement”, Goldratt and Cox evaluate the importance of constraints and bottlenecks in the manufacturing process. Goldratt defines new ways of understanding throughput, inventory and operating expenses. (Goldratt and Cox, 1993) Throughput is defined as the rate at which money is generated by the system through sales. In the case of project management, this is compared to the number of projects that are completed and for which revenue is obtained or recovered in the shortest possible time. A sale, not production, is the important factor in measuring throughput. If the product is manufactured, but if it is not sold there is no throughput. Throughput is defined from the time the raw material enters the organization till the time it is purchased by the customer and money has been paid for the product. If the product is manufactured but if it is not sold, it does not generate money.

Inventory is defined as the money the system has invested in purchasing things that it intends to sell. In project management, work in progress (WIP) inventory is compared to that of activities that are started prior to their start date needs. The accepted norm in an organizational environment was to keep all the machines/equipment working
at optimum efficiency, and the workers constantly busy is considered to be a waste by Goldratt. The ability to control the raw material that is released so that the semi-finished product from one machine is directly utilized at some other machine along the flow chain is important. Products should only be manufactured if there is a market for the product, not to build up a stock reserve for projected markets. Operational Expense is the money the system spends in order to turn inventory into throughput. Labor cost, as applicable to the manufacturing operation, is considered as an operational expense. Money that is lost due to the expense paid to convert raw material to finished product is also classified as operational expense.

Setup times are also important for the bottleneck resources. Analysis of the setup times in relation to the cost of manufacturing in a batch was also considered important by conventional standards for all resources bottleneck and non-bottlenecks before the launch of Goldratt’s new model. This setup time however, is only considered really significant on bottleneck operations in the Goldratt model. The ‘Resource Time components’ at a bottleneck resource is the process time and the setup time. A non-bottleneck is a resource whose capacity is greater than the market demand. The ‘Resource Time components’ at a non-bottleneck resource is the process time, the setup time and the idle time. The level of utilization of a non-bottleneck is not determined by its own potential but by some other constraint in the system. An hour saved at a non-bottleneck is of little importance and is just a mirage. Bottleneck should preferably be run for larger batches, to reduce setup time required for the machine. Non-bottlenecks can have smaller batch size runs; the setup time does not interfere with the process time as it does in a bottleneck operation.

Priorities have to be set in the process to determine the sequence of activities on bottleneck resources. Careful study of the time spent (queue time, wait time, transfer time and process time) by parts at any resource is required to determine the feasibility of a demand and on time delivery of a product to the customer. Many work centers are not bottlenecks; however, they have a capacity constraint and a sudden demand of a large quantity of product may cause these capacity constrained resources to cause a log jam in the process. Schedules should be established by evaluation of all the constraints and the lead-time is a factor of these constraints.

The goal for any organization therefore, is to increase profits by simultaneously increasing the Net profit, Return on Investment and the Cash Flow. A connection between these three measures has to be established for an organization. An important relevance of the TOC for projects is the “Critical Chain Scheduling.” In this, the focus is shifted from “assuring the achievement of task estimates and intermediate milestones to assuring the only date that matters—the final promised due date of a project. As a matter of fact, the scheduling mechanisms provided by Critical Chain Scheduling require the elimination of task due dates from project plans.” (Patrick, 1999)

By removing the dates from the activities in the critical path, Parkinson’s effects in the working of project planning is eliminated. Here, workers are not restricted by the start time. This is especially important in projects with a large number of activities. When allocating time for each activity project managers and planners often introduce buffer times. These buffer times might be small numbers for each activity that might be added to guard against statistical fluctuations that normally occur in each activity. While these numbers are small they add up over the entire project activities to a significant time frame. In addition, as the workers realize that they have the necessary time built in as buffers they are more likely to push out the start of the job and concentrate their efforts on other task at hand.

There have been many suggestions from consultants and theorist that elimination of the time periods or building tighter schedules can force workers to concentrate their efforts on completing the task at hand. In short, the critical chain concept uses reduced time durations for the activities that need to be conducted in the network diagram. A critical factor affect worker dedication is the constantly changing responsibilities that are entrusted to the worker from their managers and supervisors.
There is a trend of encouraging workers to multitask and perform more than one job scope simultaneously. “Multitasking is “the practice of assigning one person concurrently to two or more tasks.” Multitasking is also known as fractional head-count. One person is assigned to multiple projects simultaneously (or multiple tasks within a project simultaneously)... The “efficiency” of multitasking is a myth. Just because a resource is utilized does not mean it is productive (or genuinely efficient)” (Zultner, 2003) An employee might be responsible for completing activities on more than one project at a time. Often, the worker waste more time starting and stopping different activities. For instance, an employee performing work on four tasks per 8-hour day might devote 2 hours per task. However, he or she might require a few minutes to brush up of the activity of yesterday. That is, they might reread the work done previously to help refresh their memory. Valuable time is spent every day brush up on the past day’s work. Critical chain method stresses the importance of focusing the workers time and attention on only one job at a time. Thus, the worker can start and finish the activity without any interruption where the attention might be devoted to another task. As the activities are undertaken in one sequence, there is no need to refresh and review the past work every time it is picked up.

The milestones set in the CPM achieve approximately 80% of results. The remaining 20% are generally what results in the projects getting delayed and slipping from the final due date. (Leach, 1999)

**Advantages of using the Critical Chain Analysis method (CCAM)**

- CCAM focuses the attention of the project managers and the employees/workers needed for the project completion on the activities on the critical chain with little or no attention given to the start or the finish dates of the activities.
- CCA forces managers and decision makers to identify the constraints and bottlenecks in the process or activities. Such a methodology encourages the exploitation of the constraints and ensures that full utilization of the constraint resources is always done.
- CC encouraged managers not to start any activity too early as starting activities too early might block valuable resources that are a part of the constraint. Rather, constraint all the other resources to fulfill the needs of the activities that need the complete use of the constraint resource.
- CCAM also looks for ways by which the productivity of the constraints can be increased by improving or modifying the manner in which the constraint is used. An ideal example is eliminating multitasking, and letting the employee finish one single task from start to finish without any disruption of duties and functions for the entire period.
- This model used a deterministic method for scheduling of activities. Every input to the network model are all “singly determined values.” (Schuyler, 2002)
- The focus of this method is based on the activities and the tasks that are yet to be completed rather than focusing on the tasks that have already been completed. CPM concentrates on milestones achieved while failing to identify the trend of the future, CCAM focuses on the future and is not concerned about any saving of time in the past.
- CC espouses the elimination of “slack and float” in the times for all activities, rather it considers using the median completion time for any activity and using the variation created as a result of normal fluctuation to ensure that the activities are being completed as desired. CCAM “reduces the effects of two behavioral problems: biasing estimations and wasting slack times.” (Schuyler, 2002)
- Managers can spend more time on planning and scheduling of “feeding Buffers” of the critical chain rather than spreading out the resource buffer and project buffer over the entire network. By managing the buffers and concentrating on activities that can benefit from buffers, project managers can avoid Murphy’s
laws from delaying the project. The feeding buffer offers protection to the critical chain against uncertainty in the feeding or inputting non-critical chain. This feeding buffer can be adjusted as needed to ensure that the critical resource gets the feed as needed.

- “Resource alerts and effective prioritization of resource attention allow projects to take advantage of good luck and early task finishes while buffers protect against bad luck and later than scheduled finishes.” (Patrick, 1999) Time buffers (feeding, project and capacity buffers) should be introduced in a systematic method for dealing with stochastic (unpredictable) variability in the project life cycle.

- The CCAM strives to maintain a consistency throughout the project life period by managing the buffer times for the various activities. “Buffer management then amounts to the dynamic management of resources according to buffer contents or, equivalently, to buffer consumption levels. For example, among several competing activities, top priority in resource allocation is given to the activity whose buffer consumption is the highest, namely its slack time is the least.” (Cohen et al., 2004)

- From a conceptual point of view CCAM encourages managers to manage the project operation in a “pull” system rather than a push system.

- CCPM is conceptually easier when compared to other mathematical based project management methods such as Monte Carlo simulations and PERT analysis of network activities.

- Identifying the critical chain for the project is the most critical step. The advice and opinions of experts in the field should be sought to ensure that the critical chain selected is the correct one. Realistic times based on the median time requirements for the completion of the project should also be obtained from the “experts” in the field.

- In organizations undertaking many projects simultaneously, staggering the projects in a manner that encourages utilization of common resources at staggered times as well can help all projects move faster through the system—the throughput is increased of the organization. Staggering the projects based on the bottleneck resource is important. In this manner the resource that has the capacity constraint that impact the critical chain is never idle.

- The project buffer is an integral part of the project and has to be assigned resources and scheduled as well. The project buffer is the accumulate buffer of the entire system and “by pooling together the safety margins of the individual tasks, the protection against uncertainty is improved.” (Raz et al., 2003)

- Should more than one critical chain occur in the project then managers and decision makers are required to focus and select the critical chain that has the potential to impact the entire project the most. (Herroelen et al., 2002)

- The critical chain process forces managers to view the issue of the planning and scheduling of activities in a more holistic view thereby ensuring that project managers are aware of the issues that they face and are more willing to allocate the necessary time and resources to areas that are deemed to be more critical. (Anonymous, 2001)

- CCM forces closer interactions between team members as constant and frequent updating of progress is expected. Managers can observe slippages and changes in time for activities are more frequent intervals when compared to the critical path management

### Disadvantages of Critical Chain Method (CCM)

If CPM is complex and difficult for large projects, CCAM is even more complicated. This method requires that the managers and decision makers understand all the intricacies involved in the completion of the project.

Trust in the management not to overburden or overstress the resources is an important consideration in the CCM. Employees should not perceive the CC as a management ploy to extract superhuman work performance from them. As no
dates are set, the workers might negatively impact the project if they perceive that the management is misusing their powers.

Managers and experts of the activities are soon made aware that the estimates of time provided by them will be reduced by approximately 33%. To compensate for this factor there might be a tendency to over inflate the initial time requirements for the project. The level of over estimation by functional managers might also not be the same. (Raz et al., 2003) Some managers might overestimate by 15%, others by 50% and even others by 75%, using the standard 33% to reduce the time might not be the right way to handle the problem of over estimation.

Determining when a particular resource is needed is difficult to predict using the critical chain. Even if the activities are finished early there is not absolute guarantee that the resources needed to complete the next activity will be available.

Identifying the resources needed for the critical task has to be done at all times. This can be very labor intensive, as additional administrative duties will have to be undertaken to constantly track the requirements during the progress through the critical chain. This gets complicated just like the critical path might not always match the critical chain in the project.

Critical chain all requires that all resources constantly provide “current estimate of the time to complete their current task.” (Patrick, 1999) This requires tremendous coordination of real time information from all resources to a centralized database that can be accessed at all times by key personnel.

As with CPM, Critical Chain Project Management (CCPM) also relies heavily of software and computerization for tracking and monitoring the progress of the project.

The CCPM is applicable to projects that are more manufacturing based and this management method might not always be applicable to projects that start with a few central activities and these activities split up at various stages and then are recombined at different periods of time in the project. The predecessors and successors from several chains can create very complex networks that cannot be scrutinized by used the simplistic buffer methodology.

The critical chain and the associated buffers depend on a number of complex algorithms (resource leveling) to determine the time. CCPM however, does not specify any new or unique methodology for solving the algorithm. (Raz et al., 2003)

While Goldratt postulate that the critical chain is static and does not change, in reality the critical chain can shift and change in a manner similar to the critical path making the system very dependent on smart technology to constantly track the new critical paths for the project.

Buffer concept in CCPM also states that the resources should be offered to activities on the critical chain that have the least buffers. This factor however, does not take into account the penalties or fines that might be imposed due to non completion of other activities that might not be on the critical chain.

The CCPM also assumes that the organization is in full and complete control of all the activities and uses all the powers within its capabilities to evaluate and understand the needs of the critical chain. In reality, with the use of outsourcing capabilities and contractors many tasks and activities are not under the complete control of the project manager when compared to similar manufacturing issues that the manufacturing department might experience.

Eliminating multi tasking might not be the solution to all project management issues. Studies indicate that the effectiveness of matrix organizations is a reality. In many cases, there was “a relationship between the number of projects to which research and development personnel were assigned and key performance indicators of the firm” such as the return on investment and the rate of sales growth. (Raz et al., 2003)

It is not always practically possible to stagger projects to accommodate the resource needs of each project. Different projects can have different need of resources and technology at different stages of the project. Unless the two projects are very similar, the likelihood that the sequence of activities in the network diagram is the same might be very slim.
No matter what tool of project management used, the dependency of the planning and the execution of the task depend greatly on the skill and the dedication of the project manager and the skill and dedication of the project team. This aspect of project management on successful project completion will be discussed in detail later in this chapter.

CCPM can confuse organizations that are new to project management as they might find some of the principles of project management drastically different from the mainstream methodologies (PMBOK® Guide) that are used.

CCPM also require changes in the Management Information Systems (MIS) and the technology applications and use in the organization. These technological changes have to also be accompanied by the cultural changes with respect to the value and norms followed by the organization. The goals and the mission of the organization are also very important in the successful implementation of the CCPM methodology. It is unclear if any significant improvements in project management would be seen if the basic culture of the organization does not change.

Training and education of the project staff at all levels of the organization are needed. This becomes especially important if the organization was used to the mainstream methods of planning, scheduling and overseeing the projects. Training for new software and technology is also required for the staff involved with the CCPM to be comfortable with using the new technology.

There is also a lack of consensus between Goldratt use of the median time and the Product Development Institute use of the mean time for activity duration estimates in the critical chain.

While many of the software used for the project scheduling is very sophisticated and has many built in checks and balances the expertise of the individual evaluating the schedule and determining the critical chain is very important. This becomes very significant if there are multiple critical chains and the software picks one over the other.

The feeding buffer for non-critical items might create a mock situation of critical chains that are not realistic or accurate. False alarms in scheduling might be set up if the buffering is not managed accurately.

### Comparison between CPM and CCPM scheduling methods

CCAM introduced many new concepts that are easily incorporated in the traditional CPM management systems used for projects. If no resource contentions exist for the project activity, then the critical path and critical chain will be identical. (Spoede and Jacob, 2002) New project management software automatically allocates a project buffer at the end of the critical chain to ensure that the project is always completed by the due date. This introduction of the buffer might in fact preponing the start date for many project thereby ensuring that the projects will always be completed on time. “The idea of generating a deterministic baseline schedule and protecting it against uncertainty is sound and appeals to management.” (Herroelen et al., 2002) A quick comparison between Critical Path and Critical Chain as stated by Critical Chain Ltd is provided below (Direct extract from website). (CriticalChainLtd, 2003a)

Buffering also allows the scheduling of the last activity of the critical chain much latter than any of the other non-critical chain activities. The feeding buffer differentiates the non-critical activities

<table>
<thead>
<tr>
<th>Critical Path Approach</th>
<th>Critical Chain Project Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>The project finish is a date we think we can hit (and then we work like hell to make it)</td>
<td>The project finish is planned with a chosen level of likelihood, and assured with buffers throughout</td>
</tr>
</tbody>
</table>
There by allowing management to concentrate their efforts on more important issues. Activity float in the case of the CPM also offer some flexibility in the critical path, but it does not change the manner in which the project time can be changed. In essence, they perform the same function—cushion the entire project against any major variation in the activity time, however the manner in which they perform the cushioning differs. Uncertainties exist in every operations and projects. Elimination of all the risks in the project will result in making the project very costly and long. Finding the right balance for managing the risks and ensuring that a project is within the time and budget is important. The CCA “methodology has acted as an important eye-opener in project management practice. It correctly recognizes that the interaction between the time requirements of the project activities, the precedence relations defined among them, the activity resource requirements, and the resource availabilities has a crucial impact on the duration of a project.” (Herroelen et al., 2002) Project management strategies for any organization have to be employed based on the type of product, the life cycle of the product and the process involved in marketing of the product.

In practical implementations of CCPM methods, the dates of start and end of the project

<table>
<thead>
<tr>
<th>Critical Path Approach</th>
<th>Critical Chain Project Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>The critical path determines the start and end of the project – and the path may change during the project</td>
<td>The critical path determines the end of the project (after a project buffer is added to it), but the start is often determined by a non-critical activity. The path does not change</td>
</tr>
<tr>
<td>Variation is implicit, and assumed to “average out” over the length of the project</td>
<td>Variation is explicitly planned and managed throughout the project with buffers</td>
</tr>
<tr>
<td>To keep the project on schedule, we must keep each task on schedule according to the calendar</td>
<td>To keep the project on schedule, we manage our buffers, which allows us to absorb variation efficiently</td>
</tr>
<tr>
<td>Task start and finishes are carefully tracked. Schedule “slippage” is important and must be monitored closely</td>
<td>Buffer status is carefully tracked. When any task starts or finishes relative to the calendar is not important</td>
</tr>
<tr>
<td>People are evaluated in terms of whether their tasks are late relative to their committed calendar date for task completion</td>
<td>Half of all tasks are expected to take longer than planned, and the buffers absorb such variation</td>
</tr>
<tr>
<td>Fixed-date “Stage gate” reviews are scheduled to evaluate project progress to date</td>
<td>Floating “stage gate” reviews are triggered by phase completion, and buffer status is reviewed for project completion likelihood</td>
</tr>
<tr>
<td>The amount of slack that non-critical paths have is not as important and not tracked</td>
<td>Non-critical paths must have sufficient “feeding buffers” to protect the critical path</td>
</tr>
<tr>
<td>Making progress on every project, during every reporting period, is important, so resources are multi-tasked to keep busy</td>
<td>Multi-tasking of resources is devastating, and is avoided at ALL costs, including delaying the start of projects</td>
</tr>
</tbody>
</table>
are often used in spite of the “date-driven” behavior that Goldratt wanted to avoid in this new methodology. “Critical chain project managers do not criticize performers that overrun estimated activity durations, as long as the resources (a) start the activity as soon as they had the input, (b) work 100% on the activity (no multitasking), and (c) pass on the activity output as soon as it is completed. This is called “roadrunner” activity performance. They expect 50% of the activities to overrun.” (Leach, 1999)

CPM assumes that the managers making the decisions have extensive information about the activities and the time that it will take to complete any given project. A lot of historical data is evaluated and tracked for this purpose. The more knowledge the organization can archive and retrieve as needed the more accurate the entire CPM process is. Every organization is however not very efficient in the documentation other knowledge or the projects differ considerably. In this environment, using the concepts of the CCPM can help the project managers arrive at suitable time limits for completion of the task.

Both the CPM and the CCPM are dependent on software packages for the planning and scheduling of the various activities in the project. Different project management software using these two concepts has different strengths and limitations based on the inbuilt algorithm in the software. It is important that project managers and users of the software realize that this algorithm might not be the most suited to all situations that can arise during the project period. Depending on the starting parameters for the CPM (forward pass or the backward pass) different start and finish times will be provided and also the extent of resource leveling that is undertaken.

Although numerous project management softwares are available, they have not helped in improve the project completion times and the budget limits set for the project. (Douglas, 1993) There is no doubt that the software has reduced the time for significant analysis of the CP and the CC in the project, but the timely and within budget completion of any project depends on the extent and use of the “tools” at all stages of the project to ensure that the schedule and planning initially undertaken in maintained at all times. Initially developed schedules are not fixed and static. But, they might change as a result of the variation on the CP. The CC assumes that all tasks will offer some variation and therefore completion of preceding tasks will determine the time start for the next activity on the CC. The CCAM does identify the human element as an important variable for any project. The role of the project team and the methods used in the decision making process is also important for successful project management. A brief review of project team requirements and type of decision-making styles used will be offered later in this chapter as this topic is viewed as salient for any successful project.

The figure shown below indicates the differences between CCPM and the conventional (CPM) of project management. (Raz et al., 2003)
Leadership role in any project management and scheduling activity

Projects generally require a project manager and a functional manager. The role of these individuals and their interactions or disputes can signal the success or failure of the workers empowerment in the entire project. Most projects have a project manager. And successful project managers “are those who can plan for the unexpected and are flexible enough to accommodate the unforeseen.” (Needleman, 1993) Organizations are also increasingly using teams from various functional departments for planning and execution of the activities. Project teams are often not limited to just the organization but there might also be members from supplier and contractors who play a vital role in ensuring that the project is on time and within budget. The concept that the project leader or manager will be measured on how the team manages itself rather that how well the leader manages the team will be important. (McKinlay and Taylor, 1996) No matter what the method of planning and scheduling used by the project team, guidance and motivation by the project manager is very important.

Project leaders typically display two types of leadership styles in their dealing with others. Leadership performances are either “transactional” or “transformational.” Transactional leadership seeks to motivate followers by appealing to their own self-interest. Its principles are to motivate by the exchange process. Any commodity and product can be used in the exchange system; in many cases it can be higher monetary compensation, more prestige and power or more authority. Transformational leadership is intended to join leaders and followers in a mutual pursuit for higher purposes. Individuals who lead by encouraging participation and interest among their subordinates lead using the transformational style of leadership. Leaders using this style will try and convince their followers that they need to work together to obtain their final goals.

Project leaders should be individuals who are willing to give up technical expertise. They should also be able to communicate and converse situations and issues with a wide variety of individuals with and out of the organization who might be directly related to the project. Project leaders should be selected with care and should be groomed in advance for the position that they will take. This is especially important as the project manager or leader should be able to use sound judgment and process and activity knowledge to make calculated decisions for determining the CP or the CC depending on which method is used by the organization.

The question of selecting project leaders is often debated in organizations. Is it better to have project leaders who are promoted from within the organization who understand the culture and structure of decision-making and the manner in which all the members in the teamwork? Or is it better to recruit a project leader whose lack of familiarity with the team will help the team focus on areas where improvements are needed and who can inject fresh ideas and new thinking processes.

The human element Project teams and decision making

Operating a project based organizational environment requires attention to many details and factors that are both intrinsic and extrinsic to the organization. This section identifies the key variables that are needed for a project as manpower, technology, capabilities of the organization, and core competencies available within the organization. The first variable—manpower—is probably the most important. Every project requires people to be wholeheartedly involved in the achievement or completion of a set of goals or objectives. Of all an organization’s assets, the human element can provide the most variability and therefore require the greatest attention. (Randolph and Posner, 1992)

Most projects in organizations are accomplished with the help of teams. A team is defined as a group of people that have complimentary skills and a higher commitment to common goals. This group of people also possesses a higher degree of interdependency and interaction. (French and Bell, 1999) Team working and teams are however,
not without their own inherent problems. It is important to ensure that the team for any specific task comprises members who are knowledgeable and possess the required skills needed to carry out the task. Teams can be very fickle—the same conditions and environmental factors may produce different results based on the team members. This problem is only intensified when project teams are not in close physical contact. (Joinson, 2002) Decentralized and independent work centers and factories are an important part of modern organizations. Virtual teams for projects are becoming increasingly common in multinational corporations. When working in global project teams, identifying and hiring the right person can help develop a more cohesive team and deliver the desired results. (Kirkman et al., 2001)

Most project teams generally utilize five levels of decision-making: command, consult, majority, consensus and unanimity. It is easy to understand that these decision types are very closely related to the time factors the teams may have in arriving at a decision. When the command type of decision-making process is used, the team leader identifies the tasks at hand and designates responsibilities to all the team members. This type of decision-making can be accomplished in the shortest possible time—it however, has a major drawback. It will be difficult for the team leader to get buy-in for the task from the team members if the members do not agree with the decision made.

Unanimity, on the other hand, ensures that every member likes and accepts a decision—they have to “buy-in” to that decision. Achieving this is not easy in focused-, task- or project-oriented teams. Unanimity decisions also take a lot of time. When time is of an essence, this type of decision-making process might not be the best. Consensus is the next option; it takes time to generate consensus for any process. In consensus, the team members discuss the pros and cons of any issue extensively. A decision is made based on the discussion; every team member might not agree with it, however. Not agreeing “with” the decision is okay; not supporting the tasks and functions required completion once the decision is made however, is damaging to the team. And many time-constrained projects may suffer as a result of the excessive time spent in generating consensus.

Often, many teams do not even consider the consult and buy in option, which can be a time-saver and also involve the entire team. In this situation, the project leader can discuss the plan of action with the people who will be responsible in the execution of tasks and collects opinions and ideas from them. Based on this, the team leader can make a decision. This style of decision-making is faster than the majority, consensus and unanimity type of decision-making. But one can ask the question whether the leader consulted every team member, making them feel appreciated and valued. Doing so may generate sufficient enthusiasm in the team and help in the implementation of the task.

**Changing face of projects and the role of CPM and CCPM**

Software and hardware technology integration is required for all project endeavors. Modern day organizations are characterized by very dispersed facility location and human expertise and there has to be a common system interface for connecting all the sub systems together for the purpose of completing the project. Project plans and designs have to be communicated frequently and effectively to all members in the project team and this requires a high sophistication of equipment and skills. Projects are generally undertaken in an organization and there is a perception that when completed the end result will add considerable value to the business, while improving profitability.

All projects rely heavily on knowledge of the organization in handling the desired task. Knowledge is a dynamic blend of structured expertise, values, contextual information and insight. It provides a framework for evaluating and integrating experiences and information. Knowledge defines the intellectual assets of an organization. The four knowledge transfer channels identified are: externalization, combination, internalization, and socialization. Various facets, levels and types of knowledge have been identified in management theory literature. In any organization, knowledge, over a period of time
Knowledge can be classified as “Explicit” and “Tacit”. Explicit knowledge is the knowledge that is objective and rational. Explicit knowledge can be expressed in formal and systematic language. Tacit knowledge is subjective, experiential and hard to formalize and communicate. Knowledge transfer occurs in one of four forms: from tacit to tacit; from explicit to explicit; from tacit to explicit; or from explicit to tacit. Knowledge transfer is a two-part process, sending and receiving. Knowledge transfer can only take place when knowledge is transmitted by the sender and received by the receiver.

Many projects in the present workplace are also undertaken using virtual teams. The virtual workplace is defined as one in which the employees work remotely from the organization, that is away from managers and peers. (Cascio, 2000) Virtual teams are never in physical proximity with each other. Studies indicate that virtual teams communicate differently as compared to face-to-face teams. (Warkentin et al., 1997) The virtual team set up to undertake design and manufacture of the next generation of Boeing planes is an ideal example of the trend of using this type of setting for handling major R & D projects. (Foster, 2003) The need for smaller aircrafts flying longer routes was emerging. Boeing did not have the design to meet this new demand. Understanding the pros and cons of virtual teams, Boeing set up 238 virtual design teams to tackle the task. Standardization of the technology and using a common platform for information transfer is important. The airline pioneer ensured that these systems were in place to facilitate these technology systems. Factors such as manager-control and supervision are also eliminated in a virtual team setup.

Managers overseeing the operation have to be confident in the work ethics and accountability of the virtual employees. Keeping every member of the team aware of changes and periodic reviews and meeting can keep these members constantly in the loop. The advantages that Boeing gained as a result of using virtual teams were tremendous for this project. The company was able to bring to market a new plane in two years with a lower number of design changes and rework. The success of this mission also helped provide the foundation for virtual teams that today have been very successful in building the International Space Station. The task of 16 countries working together in designing the various modules of the space station while being geographically distant has been amazing. The critical nature of the work, the essential requirements that all pasts fit in space and the high profile nature of the task has ensured that the virtual teams work together to achieve the higher objective.

It is clear that handling these types of projects using any one method of project management is not the most ideal. CPM and CCPM can help organizations undertaking projects of large magnitude in terms of cost and time to better understand the constraints, bottlenecks and social and cultural issues that they might face in addition to the process and manufacturing constraints that might be a part of the activity completion.

**Discussion**

Depending on the situation for which it is used CPM and CCAM can be both very effective. The CPM has been in use for a long time and while not perfect offers organizations a suitable methodology to manage projects. At it essence, it follows almost a similar concept as the scientific management that was introduced for managing labor by Taylor in the early 1900. By breaking up a project into small manageable sections that comprise of tasks and activities even enormous projects could be handled as small and discrete tasks that when linked together resulted in the creation of a completed project. The significance of this method was that it assigned dates and not just the times associated with the completion for the project.
The Human element

Human nature being what it is there is a natural procrastination by a portion of the working population to push out completing a task or activity to the last possible date and then racing to complete the activity by the due date. It is important however, to not that all people do not work in this manner but even a few who work in this fashion have the ability to impact the others who work at the pace specified in the project activity. As resources are also often used for major than one project at a time, worker procrastination is also compounded by the demand for the same labor and equipment resources. Man, machine, material and money are essential requirements and resources for any organization. Project scheduling and planning have to ensure that these resources are used in the most optimized manner.

Human relationships especially in the work place are complex and the dynamic that exist between worker and management or between worker and another worker cannot be easily compartmentalized and segregated by the manager overseeing the operations in the organization. “When people feel they are being treated like objects or problems, safety and trust plummet and well-honed defense mechanisms of fight and flight come online. While most people at work are too savvy to act out these maneuvers in their most overt and extreme forms, they adopt subtle and powerful channels of expression, usually of the so-called “passive-aggressive” variety.” (Brightman, 2004)

The Critical chain addressed the human element of project management in a manner that was not previously undertaken. Goldratt believed that by eliminating the start and finish days for activities the worker is not presented with a mental check of the dates that the activity was required to be finished by. The fact that all managers involved with the activities built sufficient time into the activity task in order to have 95% confidence that their workers would finish the task was well known.

Training and educating the project worker

Training and education of the worker to move from the traditional methods of depending on the times set up the CPM software to one where the worker has to be motivated to work at a constant intensity in order to ensure that the activity is finished in the least time possible accounting for normal statistical variances in the activity. Changing the mindset of the worker is a difficult task and while many organizational development and change agents believe the task can be accomplished in reality changing the culture of the organization is very difficult. Unless the worker honestly perceives that the changes undertaken by the management will help the completion of the task in a more efficient manner without creating undue stress on the worker the changes in project management styles will be viewed as another management fad that is implemented by the management.

By offering adequate training to the employees, organizations are able to increase retention rates and employee confidence. (Sullivan, 2003) Higher retention rates for an organization generally translate to higher productivity and a more flexible workforce. Trained employees require lesser supervision, thereby delivering higher quality products, and consequently, higher profits. Edwards Deming, one of the early advocates of quality in organizations, believed that better job-related training is instrumental in improving the quality of work and products manufactured in an organization. (DeVor et al., 1992) The economic boom of the past few decades has indicated how a trained and educated workforce can improve the economy of a region. (Poirier and Bauer, 2000) A lack of integration between what the manager perceives that is needed and the efforts that are taken to ensure that the need is satisfied by proper training is often the reason for many of the new management styles to fail in organizations.

All organizations and companies have internal organizational structures that have been set up over time in order to ensure that the tasks required to be completed by the organization has been completed.
in the manner desired. Often, these structures are the result of organizations selecting and keeping the processes and the systems that work best for them in the situation and industry within which they operate. The fact that even organizations within the same industry have radically different ways of managing projects is testimony to the fact that a ‘one-size-fit-all’ project management method will not work for all. Among the big five auto manufacturers (Ford, General Motors, Daimler-Chrysler, Toyota and Honda) the methods in which they handle new product development is testimony to the fact.

For the TOC, one assumption made is that the worker selected for the task will always be able to complete the task required by knowledge and expertise in the field. Little or no literature is provided on how organizations using project teams can train and develop their personnel especially when the workers are constantly involved with some activity or the other. Even in the example of the Modern Company and the University provided by Goldratt in the book Critical Chain, the fact remains that all the individuals involved in projects are assumed to be experts in their field. In reality organizations do not always have individuals within their projects who have 10-15 years of experience within the organization. Job-hopping is a factor that has not been focused on in the critical chain human resources management. It is assumed that while the worker is an important part the worker might not be with the company throughout the entire duration of the project.

Motivation and guidance of the worker is also very important. Elton Mayo, as far back as the 1920, with the help of the Hawthorne’s experiments, showed that workers could be encouraged and motivated to perform to higher levels of productivity by factors other than high salaries. He concluded that every individual felt a need for recognition, security and sense of belonging. These factors played an important role in a workers life, since work-activities and their consequences in modern times inevitably extend to the home and the worker’s social life. The environment, both internal (from within the work environment) and external factors that affect the organization, plays an important role in the workers life. Elton Mayo was the first to bring the human element into the equation of management. (Mayo, 1977) Goldratt in the book the “Goal” also drew a parallel between the personal issues that Alex Rego faced and problems that he carried over from his work life into his personal life.

“Studies of commercial projects noted cost and duration estimates overran by 70 and 40 percent respectively.” (Sciforma, 2004) In many cases the customer of the project can be either internal (another department in the organization or building a facility for the organization) or external (supplier to another organizations, contractors for a construction job.) The successful completion of the task and activities also determines the relationship that the project manager or team can have with these external customers. The ability to nurture and develop long-term relationships with customers whether internal or external can help the organization have a competitive advantage over its competitors. (Day, 2000) Organizations are constantly looking for ways and means to improve customer relationships. In the past, the customer was often perceived as just external to the company. Peter Drucker stated that markets are not passive entities beyond the control of the entrepreneur or organization; rather, they are very interlinked. Markets can also be influenced. (Drucker, 1954)

**Scheduling of task and worker performance**

Scheduling tools have helped projects. CPM and PERT were the first to identify the benefits that can be obtained by using a highly disciplined and methodical way to handle the requirements of the job. (Thomassen and Butterfield, 1993) Calendar constraints were considered an important part of the scheduling process and project teams to ensure that the activity is progressing as desired often use both manual and electronic calendars. Project managers and team members have got very used to using this method for tracking the project and the requirements of the CCPM of eliminating the use of calendars can create anxiety in individuals...
used to having a deadline. Implicit and explicit expectations of the project managers of the workers can also affect the anxiety that workers might face to complete the project in the absence of a deadline. The human thought process of “things were always done this way” exists in most companies. The older the operation and the more established the business the greater the resistance to the new methods.

People also have different paces at which they can work to complete a task. CPM assumes the standard times for a task allowing for the variance of each worker undertaking the activity. In the case of the CCPM method, different working speeds might make some workers “look bad” even though the work they undertake might be defect free and of superior quality. CCPM offers little insights to how managers at the lower levels can help motivate and encourage workers with different working styles.

One of the best features of CCPM is the advance warning and awareness that can be provided to resources that have constraints and are on the critical chain of activities to be completed. This feature can help project team members become aware of the resource needs prior to the resource actually needing it. For example, if a machine in the welding department is on the critical chain and the feeding task has the potential to be completed 3 days ahead of the expected completion time, advance warning can be offered to the welder working on the machine to either complete the task he is conducting on the machine by the date the critical chain task will advance to this machine. Thus, it is easier to reallocate resources in a very short period of time without major disruption in the project time.

The CCAM also focuses attention on identifying the root cause of the problem rather than attempting to topically fix the problem when it occurs. Managers and project workers are constantly aware that they have to identify the causes of the problem when they occur rather than allowing the issue to slide because they have more time to “fix a mistake” with the help of the floats. Many of the symptoms that induce the problems are often rarely technical but rather more physiological resistance to the changes in organization. CCPM methods encourage managers and workers to look ahead rather than dwell on the fact that task and activities were completed in the past for the said project. By combining this feature with CPM, senior management can encourage managers and supervisors to look forwards towards the tasks that need to be completed and the strategies and planning that are needed for the tasks still to come.

In the past, with CPM, decision makers were often faced with reviewing past as well as future tasks and activities that needed to be completed. CCPM reduces the amount of paperwork that the manager has to review and offers managers the chance to stress on features that are more important to the critical chain. CCPM method encourages a proactive behavior from all involved rather than a reactive behavior to an issue or a situation that might arise in the organization.

**Interpersonal relationship in project team and their impact on performance**

Project teams also face more scrutiny with the CCPM method as the focus is on the task yet to be completed. Smaller volume of paperwork also allows for greater in depth analysis of the critical chain. This attention requires that teams work more closely together and achieve the desired results. Issues such as conflicts and differences of opinions can be very damaging for any team, but in a project team dedicated to a critical path cannot afford to be embroiled in major conflicts and difference of opinions. There are generally two types of conflicts observed in organizational settings—emotional and cognitive. The first being “Emotional conflict” is personal. The manifestations are often defensive and based on resent. It is also known as “A-type conflict” or “affective conflict.” Emotional conflict is rooted in anger, personal friction, personality clashes, ego and tension. “Cognitive conflicts,” on the other hand are largely depersonalized; also know as “C-type conflict,” consist of argumentation about the merits of ideas, plans and projects. At an interpersonal level there might be two reasons
why conflicts originate. The first can be attributed to group identity. This conflict arises when individuals’ personalities and behavior patterns do not synchronize. In the second case, the conflicts arise not from the individual’s personality but rather from the group or team with which he or she associates.

Conflicts in teams can be generally classified into three types: relationship conflicts, task conflicts and process conflicts. Each of these conflicts can have different impacts on teams within an organization. (Jackson et al., 2003) Interpersonal conflicts or A-type conflicts can make working conditions difficult in an organization or within a team. (Van Slyke, 1999) Emotional and personal feeling can distort and overshadow the purpose or agenda of the team making task execution and completion difficult. This situation might devolve into a win-lose competition where each disputing group is unwilling to arrive at a compromise.

There are three factors that affect the behavior of employees within an organization. They are personal, organizational and environmental. Psychological characteristics (perception of empowerment, involvement in decision making), demographic information, job experience are personal factors that affect a worker’s performance. Supervisory control, managerial styles and compensation models (Satisfaction theory, Incentive theory or Intrinsic theory of compensation) (Handy, 1993) and the control systems used constitute the organizational factors that can affect worker performance.

**Technical issues of application of CCPM and CPM**

From a technical standpoint, project managers can conceivably use the advantages of both the CPM and the CCPM methodology. Both methods do a lot to increase the knowledge of the organization towards the activities being performed. Intellectual capital is knowledge, which is considered an asset to the organization. There are four types of intellectual capital: human capital, structural capital, customer capital, and social capital. (Svelby, 2001) The CCA address the topic intellectual capital that might be missed by the CPM. CCPM also address the issue of start time from the backward pass thereby ensuring that the last possible time allowing workers lesser opportunities for wastage of time on the job. In the CPM, scheduling is often done as-soon-as-possible (ASAP) from the project start date whereas the CCPM asks are scheduled as-late-as-possible (ALAP) based upon the target finish date.

The critics of the CCM process however see no difference between the float times that the CPM uses and the buffer that the CCM uses. The fact that both these methods understand that variance does occur in the task creates little differences, as too how the “safety net” is set up for these variances. The use of the mean and the median of the times by many users of the CCPM also create a confusion of which method is the most appropriate for the project management process. Another danger in the CCPM process is that by using the ALAP method there is the risk that all tasks become critical due to the time constraints on the resources needed for the job.

Another major pitfall of CCPM is that many “commercial software packages do not embody optimal algorithms for resource leveling and resource-constrained scheduling, but rely on the use of simple priority rules for generating a precedence and resource feasible schedule.” (Herroelen and Leus, 2001) Many software packages used for project scheduling use algorithms that are not publicly available as the software companies consider their propriety knowledge as such managers are not sure about the reasons why certain paths might be selected as critical chains over others. CCPM attempts, at all times, to reduce the project’s WIP. It advocates delaying the task until the last possible time. In this situation, should there be a rework or a major hurdle, the snowball effect of this occurrence can result in major delays of the project. In addition, CCPM does not address “practically relevant problems, such as the resource leveling problem, the resource-constrained project scheduling problem under generalized precedence constraints, the time/cost and time/resource trade-off problem,
and the multi-mode resource-constrained project scheduling problem.” (Herroelen and Leus, 2001)

**What CCPM offers to CPM**

The book Critical Path however helps highlight other organizational issues that hamper successful project management—namely the impact of management control over the project. The constant tug-a-war between senior management to reduce time and cost of project is always strongly opposed by lower level managers and workers who are constantly seeking more time and resources for completing the task at hand. Management generally controls the capital in an organization. Labor, on the other hand, has always offered some “resistance” to the managerial functions. Different functional departments involved with the project management might also impact the perception of time and resource reduction/increases that take place within the realms of the project management negotiations.

While social and professional relationships among different strata of an organizations structure have changed tremendously over the years, employer attitudes towards workers and potential conflicts between managers, supervisors and workers are real and exist in almost all organizations. To a major extent, CCPM simplifies the issues of labor management and mentality in organizations. Project managers are actively involved with the WBS but also “design it to validate some core assumptions related to the project’s fiscal requirements.” (Elton and Roe, 1998)

CCPM encourages the entire project team to refocus on coordination and communication of task and mission—rather than project team members working in functional silos in organizations. While many people covet the opportunity to manage and direct subordinates, every individual does not posses the ideal leadership qualities. The project leader had to realize that he or she now had to provide the holistic viewpoint of the project and have the entire picture in mind. No individual is perfect. Management skills can be developed—the qualities required can be learned.

Poor work ethics imply that the project members do not have a vision and a dream for the company in the long run. When leaders do not appreciate good quality of work that is done, employees can get disillusioned. Motivational levels can drop and the quality of the work generated by a worker can be seriously affected. In any project team, interpersonal communication and mutual respect is important. Managing time, communication and resources efficiently is very important for the team if it has to achieve its objectives.

Trust, is the most important factor in any organizational relationship. (Child, 2001) In the business sense, trust is having confidence in the partner or workers to conduct and perform their task in a manner agreed on. This confidence will vary depending on a number of external factors such as the past relationships that the worker may have had with the leader, the culture and values of the worker and the interaction of the task and the skills required with the worker’s skill set. A project team’s success depends on the level of mutual accountability, contribution and shared values that the group members feel towards achieving the goal.

Values often tell a lot about someone or something—both for an organization as well as for an individual. Employees are constantly seeking satisfaction and meaning from their work lives, and more balance in their lives as a whole. By defining the values and the culture of the work place employees who are more in tune with the organization will come aboard. The social, cultural and political factors greatly affect the organization. Competency management can also help organizations understand their skill set requirement. Human motivation encompasses a wide variety of topics and arenas. Factors affecting motivation can be intrinsic as well as extrinsic to the individual and the environment in which the individual operates. Every individual has his or her own individuality and style—a true comparison is not possible. A lot of the value and innovation in organizations today comes from workers knowledge and intelligent work processes, which may be technically very difficult to evaluate and appraise.
These “social and soft” aspects of management are some of the important factors that CCPM introduces to organizations. “Project performance is often less a matter of understanding the constraints of the project and more a function of the personal skills and capabilities of the potential leaders available.” (Elton and Roe, 1998) CCPM also challenges the traditional concepts of performance measurement for the individual and the project. Projects often lose direction and run out or resources due to the lack of understanding of the task between the senior business managers, project managers and functional managers. It should be clear to all involved in a project however, that variability is an integral part of the process and as such managers should be able to deal with the occurrence of these variables within the system.

Another major pitfall of the CPM and the CCPM is the extent of the paperwork required for the entire process. Often, individuals having to constantly deal with this problem consider it a major hurdle in the entire monitoring process. (Haughey, N.D.) Often, senior managers and decision makers do not have the time to completely evaluate and review the entire contents of the report or document handed to them by their subordinates. Failure to periodically review document can result in errors and slippages of the project getting no notice at the time where minor adjustments might manage to put the project back on track. To avoid this problem, senior managers can afford individual project managers more autonomy of their tasks and greater job-enrichment. Job-enrichment is referred to the latitude and personal responsibility that is conferred on a worker to allow him or her to perform their task in a manner that they perceive as comfortable and the best option while still producing the desired outcomes in manner specified and with the quality desired. This drastically differs from the concept of job-enlargement where the worker is forced to perform and undertaken more than his share of work in an attempt by the management to reorganize or restructure the job scope of the individual in any given position.

Job-enrichment has to be a constant process and has to be communicated effectively to all members in the organization. Defining rules and guidelines is also important when promoting job-enrichment for the workers. When all involved in the process are able to understand and comprehend the expectations that the task requires, fewer mistakes and errors are made during the execution of the task. Building a value-based communication both vertically and horizontally throughout the organization is necessary.

Many organizations using the project style of management go through the tedious process of developing a “project management process, training the staff, and then never providing any long-term support and follow-up. Project management methodology should be thought of as a tangible product that is developed, supported, and enhanced.” (Mochal, 2002) This is especially important when the company wishes to make investments in purchasing and developing software for CPM and CCPM methods in the organization. The initial cost of the software required for these management tools is very high along with the cost of training of the worker. If the tool is not used to its full extent then complete benefits cannot be obtained from this tool.

As the scope of the project increases the members working on projects tend to become more specialized in a specific task and cross training is rarely done. Cross training is different from multitasking. In cross training, the worker is trained in more than one skill set. This can help the organization reduce the dependency on the constrained resources and offer more flexibility for completion of the task as planned.

Supporting services for the project team is very important. This includes administrative staff and the IT staff that is needed to track and develop the future needs of the project as it grows through the various phases. CPM and CCPM often assume that the skill requirements for tackling a project are always available and place low emphasis on the development of this skill. The fact that construction project fare much better relatively when compared to projects undertaken in other industries is that the potential project managers for construction projects are groomed for years prior to allowing them to head their own project.
Many other industries make the mistake of promoting a technical expertise individual into the project management position without considering if the individual will be an ideal person to lead and manage people under his or her supervision. Project work is often unique when compared to manufacturing or production. Often, project members have to conceive, plan and monitor a solution from infancy to completion. In the process, the project might pass through various stages of evolution and change. Project workers need to be resilient enough to manage the changes and modifications as needed. While the CPM and the CCPM might suggest the direction to be taken, finally it is up to the worker to make the necessary change in the schedule and the process.

Lastly, time management in any project is critical. Time is a commodity that has limited "shelf" life. The significance of the fact that it cannot be recovered is the main characteristic that has made people place a lot of importance and value on the measure of time. Time management has taken on strategic importance for organizations and corporations due to the value of money associated with the time. The concept of time value of money is becoming of great importance to determine the effectiveness and competitiveness of organization. Time management can also be used to measure the performance levels of individual workers and employees. Completing a project on time and up to the required quality can help companies and organizations build a reputation for reliability in the market.

Commitment and dedication is required if an individual wants to handle time more efficiently. This means talking less on the telephone, keeping office communication to a defined minimum, finding ways to handle routine tasks less frequently. It is very important to set a routine and stay true to it, under most circumstances. Things will change and complications will arise in any situation. It is unreasonable to not expect this. Managers and supervisors can manage their tasks and consequently their time better if they learn to delegate tasks and responsibilities to their subordinates. (Chapman, 2001, Blair, 2003) It may take some time in the initial stages to train and educate a subordinate in the tasks to be completed; if the worker has learnt the task properly however, delegating may leave greater time for the manager to handle other more important decision-making tasks. When considering time management, any individuals should be judicious in identifying which task can be done by themselves and the tasks that may be completed more effectively by contracting it out to another person.

**Conclusion and Recommendation**

The CPM and the CCPM are both valuable tools that any organization can use successfully to manage their projects. “Scope management, cost management, and time management” are important variables for projects. (Anbari, 2003) Every successful project is characterized by sound project analysis using some form of network diagram that breaks up even very massive projects into small and manageable discrete tasks that can be performed. Understanding the true scope and extent of the project is often the primary and critical step to build a sound project management foundation for any undertaking. Projects differ considerable. Some projects might be very short while other might stretch for years. In addition, some projects might be routine and the company and the project team might undertake similar projects periodically—home construction is one example of this type of project. Projects such as the International Space Station will take years to complete. And even after completion, it will require a maintenance and upkeep program. Making random assumptions that the needs of all projects are similar and therefore can be understood via a common methodology is presumptuous.

CPM and the CCPM both use a safety net to manage the uncertainty that arise in the process of completing the project. Where CPM uses floats for every activity, CCPM uses buffers at the end of the activity and at the feeding of non-critical activities into the critical activities. CPM has been in use from the 1950s. It has offered project managers with effective ways to estimate the time and cost needs of the project. The critical path is not static.
It changes, emphasizing that the project manager and senior managers have to constantly review and monitor the process. This helps ensure that the activities are being completed in the manner in which they were planned. Scheduling of project-based activities can be done by using either the forward or the backward pass in CPM. During scheduling, every task and activity should be reviewed using compatible calendars. Using too many different calendars can confuse the decision process. Even if great care is taken to prevent errors, the schedule does not stay fixed and as a result the constantly changing path might create errors at later stages of the project if the same individual does not perform the change. CCPM however, does not recommend changing the CC schedule. Rather, adjusting and managing the buffers in the process is considered to be more appropriate. Too many changes in CCPM will confuse and demoralize the worker in the long run.

As stated earlier, every project is not similar. And the manner in which CPM and CCPM is implemented and used also differs considerably. Organizational culture and values play a significant role in the process of planning and scheduling of activities. Knowledge that can be harnessed from within an organization also has the potential to determine the accuracy and the relevance of the data and information available to managers at the planning stages. More accurately the knowledge compilation better the chances that the knowledge will help improve the decision making process. Knowledge and information should flow from all directions: i.e., from management to workers and from workers to management. Restricting the flow of information can prove disastrous. Management, also believing that they have the sole control over the information, can de-motivate and reduce the involvement of the worker in the project completion process.

With the use of virtual teams and global players for various task completions, project management has become even more complicated. The earlier example of Boeing offered in Chapter 3 indicates that projects are no longer restricted by geographical boundaries. Ensuring that all parties involved in the project use CPM or CCPM in a similar manner is also critical. In many situations final consumer in the project chain might dictate the methods that are to be used by the other parties feeding the CP or CC.

There are some advantages of CCPM that can greatly enhance CPM. The elimination of start- and end-dates, while a seemingly small change, can greatly affect the mentality of the worker. Perceptions play an important role in the manner by which a worker undertakes his or her responsibilities so that a task may be completed. Most employed individuals either subconsciously or consciously tend to follow Parkinson’s Law. Restructuring and reengineering of companies have also reduced the number of employees available to complete any task—the reduction of the labor resource can introduce constraints that might not have been foreseen during the initial planning stages. CCPM states that it is inefficient to have employees multitask on different projects. In reality however, this is an option that is unavailable to individuals working on projects. Many software tools often fail to identify the over utilization of the labor resource for the completion of any task. Capital resources also determine the extent of equipment and labor resources available for any project. CCPM identifies that managing resources can help project managers monitor the task completion. At the same time they project the need of these resources for future tasks.

CPM method looks backwards. It often makes the manager (functional or project) look good in the short term. This is due to the achievement of the milestones set in completing tasks. On the other hand, CCPM looks forward. It does not always stress the finished part of the project. One of the flaws of the CCPM method however, is that it does not account for the time required to rework or if the scope and quality of the activity is compromised. Slippage on any of the activities on the critical chain will eat consume the project buffer time set at the end of the project. Critics of this process are also quick to point out that estimation of the project buffer still relies on the variability information provided through the CPM method. In essence, it might be more difficult.
to get realistic times for the CCPM during the planning stages.

The theory of constraint concept, when first introduced, focused purely on production and manufacturing. Project management often does not have the same external and internal variables. They are often subjected to factors that might be beyond the scope of the management of a system that is closed. At this point in time, CCPM offers organizations a method of incorporating the human element into the CPM method. When used, the critical path method and the CCPM method can greatly complement each other to create an environment where project managers, functional managers and senior management can collectively review the technical, the social, the environmental and the labor factors that might affect the completion of the project.

The decision-making process does not significantly change with the use of any of the tools from the project team management point of view. The decision process however, changes with respect to the extent of risk and uncertainty that the two methods might utilize. When CPM was initially introduced, it was done for projects for which historical data could be obtained. PERT was used for projects that did not have any precedence or information available for tasks, times or cost.

Over the years however, CPM and PERT were often combined together, thereby introducing the uncertainty aspect of PERT into the deterministic nature of CPM. CCPM method realizes the importance of statistical process control in determining time requirements for task and activities. The controversy over using the mean or the median for determining the times of the bell curve for any task is still to be resolved. As discussed in Chapter 2, different managers might have different tolerances for risk, and therefore utilize different confidence intervals in determining time. Using one standard method for reduction of the basic estimate would not be appropriate.

Each organization using CCPM would have to identify its level of tolerance of risk and the possible decision-making strategies that it could use in case of project slippage. Both these methods discussed in the study depend extensively on algorithms solved by many of the commercial software packages available. It is important however, that organizations realize that algorithms need modification to match the nature of the project and the organizational missions and goals. Project managers are often not experts at understanding the working of software; rather, they possess the technical expertise to identify if the results generated by the software are logical and appropriate for the software. This requires developing and training individuals both to use the software and to understand the caveats that have to be considered prior to selection of the best path. Software can only aid and help in the decision making process. And, finally, it is the manager or supervisor who makes the decisions to choose a certain path. There is great potential for both these tools if properly utilized. The extent of utilization will be based on how these tools stand the test of time in real world situations.

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