A STUDY ON THE APPLICATIONS OF CRITICAL CHAIN MANAGEMENT IN THE PROJECTS OF CONSTRUCTION INDUSTRY

AMANCHARLA MANIKANTA[1], NADENDLA RAFI[2]

[1] M.Tech Student, Dept. of Civil Engineering in Global College of Engineering and Technology, Rayalapanthulapalle, KADAPA, AP.

[2]Assistant professor, Dept. of Civil Engineering, Global College of Engineering and Technology, Rayalapanthulapalle, KADAPA, AP

ABSTRACT:

The planning, organisation, and administration of a project's resources are the primary focuses of project management. This is done with the intention of ensuring the effective accomplishment of certain project goals and objectives. It is about making promises in the face of moderate to high levels of uncertainty, along with large degrees of complexity and interdependencies, and then sticking to those commitments. Before beginning a project, it is customary in the majority of settings devoted to project management to establish legally enforceable commitments with regard to three distinct aspects of the project. These aspects include the project's (i) schedule or time, (ii) resources or budget, and (iii) scope, quality or performance goals. If any of these obligations are not met, it is possible that the whole project may be labelled a failure, which will have severe repercussions for all of the stakeholders. Evidence reveals that there is a significant proportion of project management failure across all sectors, despite the fact that each sector has its fair number of projects that are completed successfully each year. According to the findings of a number of studies, just 44% of projects are regularly finished on time, projects typically conclude at 222% of the period first anticipated, 189% of the money originally budgeted, 70% of projects fall short of their projected scope, and 30% of projects are terminated before they are finished. All of this laid the groundwork in the 1970s for the creation of a system of project management known as the critical chain approach. The Critical Path Method (CPM) is a method of scheduling that has been used extensively for a very long time in a variety of sectors, including construction. On the other hand, as a result of the more competitive nature of the business environment, more stringent time limitations are becoming the industry standard. As a direct consequence of this, an increasing number of projects are falling behind schedule. Because of this, a novel approach to project management known as the Critical Chain Project Management (CCPM) Technique was finally developed. The Critical Chain is a chain of both precedence and resource-dependent activities that Eliyahu M. Goldratt devised in 1997 based on the Theory of Constraints (TOC). It is the sequence of these jobs that precludes a project from being finished in a shorter amount of time provided that there are limited resources. The Critical Chain Project Management (CCPM) methodology operates on the presumption that projects are plagued by uncertainty, that task times are exaggerated in an effort to prevent the negative impacts of such uncertainty, but in practise, such extra safety time is squandered. The CCPM addresses this issue by ensuring that sufficient buffer management is in place. The CCPM framework is adaptable enough to work in either a single- or multi-project setting. By using CCPM, the projects will be finished ahead of schedule while making effective use of the resources. Nevertheless, the building sector does not yet make widespread use of it. The findings of a research that was carried out in the field using the CCPM approach are presented in this thesis.

I. INTRODUCTION

Project management is the application of processes, methods, skills, knowledge and experience to achieve specific project objectives according to project acceptance criteria. There is limited time for project management and limited delivery to the budget.

One key factor that separates project management from mere ‘management’ is that it has limited time to final delivery and management, which is an ongoing process. For this reason the project professional needs a wide range of skills; often technical skills, and public management skills and good business acumen.

In short, the project management goal is successful in the start-up, planning, execution, control and closure of project processes, as well as the implementation of all agreed objectives on the scope, time, quality and monitoring objectives to guide the project’s operations. Team. Development. Budget standards.

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IMPORTANCE OF PROJECT MANAGEMENT

- Strategic Alignment
- Leadership
- Clear Focus & Objectives
- Realistic Project Planning
- Quality Control
- Risk Management
- Orderly Process
- Continuous Oversight
- Subject Matter Expertise
- Managing and Learning from Success and Failure
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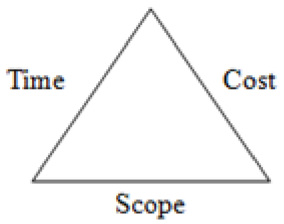
PROJECT CHARACTERISTICS

Despite above diversities, projects share the following common characteristics.

- Unique in nature.
- Have definite objectives (goals) to achieve.
- Requires set of resources.
- Have a specific time frame for completion with a definite start and finish.
- Involves risk and uncertainty.
- Requires cross-functional teams and interdisciplinary approach.

Project Performance Dimensions

The three main dimensions that define project performance are scope, time and resources. These parameters are interconnected. The relationship is usually referred to as an equilateral triangle. The relationship is shown in the below picture.



Project performance dimensions

OBJECTIVE AND SCOPE OF THE PROJECT

The Critical Chain Project Management Theory is based on methods and algorithms derived from obstacles. CCPM idea in 1997 Eliyahu M. Goldratt's book, Critical Chain. The application of CCPM is credited with achieving 10% to 50% faster and / or cheaper projects (i.e. CPM, PERT, Gantt, etc.) than the traditional methods developed from 1910 to 1950 From several studies, only 44% of projects are typically completed on time, with projects typically 222% of the original planned period, 189% of the actual budgeted expenditure, 70% of the projects within the planned scope (technical content distribution) and 30% canceled before completion.

This traditional data is largely avoided by CCPM. In general, the CCPM case study reports 95% on-time and on-budget completion when CCPM is properly applied. Execution of the criminal chain reduced lead-time by 69%, cycle time by 66%, scheduled date performance by 60%, inventory levels by 50% and revenue / output by 68%.

II LITERATURE REVIEW

- Francosis Retief et al. (2002) gave a short summary of how critical chain scheduling works in project management. The author says that using CCPM to plan a project can improve how well it works. Changing the way a team works to get rid of bad habits and using buffers to protect the project's end date are two ways to improve project performance. The paper also talks about the different ways that people hold back on tasks that involve safety and move forward too quickly for the safety that is available. People talked about the main differences between CCPM and CPM practises, like how CCPM cuts activity times by 50%, how it uses activity and resource logic to build a critical chain, how it uses buffers to protect the critical chain from delays, etc. All of these important parts of CCPM help to finish a project faster and give executives an effective tool for project management. Organisations should be very careful when adopting CCPM techniques. The paper also talks about the problems an organisation might face if it tries to use a CC approach.
- Tzvi Raz et al. (2003) looked at the most important parts of Critical Chain Project Management (CCPM), such as duration estimates, buffer design assessments, progress measurement, task completion notification, and time for setting priorities. The authors have done a thorough analysis of CCPM by using both written and real-world information. The new point includes practises for estimating the length of a project, a project network diagram, how strong the critical chain is, and how well different resources work for a product in a multitasking process and operational environment. The CCPM looks at the idea of large project management and the costs that come with it. The CCPM says that it has a number of useful ideas, but it doesn't give a complete solution to project management.

- Izac Cohen et al. (2004) look at the control process of CC and a few other options. They show that CC is not enough to stop projects from being late, and that these other options may give better results. The author looked at the control process of a multi-project environment, which was similar to organisations in the aeroplane industry, and showed that the buffer size may not be enough to finish the schedule on time. Instead, different control methods, like QSC, ConPIP, and MinSLK, should be used to get the same or better performance. More research needs to be done to come up with better ways to schedule and keep track of multiple projects.
- In 2005, Lawrence P. Leach et al. "Measures drive actions that move you towards the goal," says Goldratt's "The Haystack Syndrome," which the author cites. It means that you have to keep track of how well you're doing, which can help you figure out how your choices are affecting your ability to reach the end goal. The paper talks about different levels of action that were used to make a decision about the buffer. They were put into three groups: no action, plan, and carry out the plan. The author used a method in which the buffers were first put in order based on how the chain worked. Second, there should be regular checks on how the project is going and how much of the buffer is being used. Third, plans should be made to speed up the project if the buffer consumption goes over a certain threshold that has already been set. If the second pre-set threshold is passed, the plans should be put into action. Based on these thresholds, the author made fever charts that show how much of the feeding path has been finished against how much of the buffer has been used. It was suggested that fever charts should be looked at regularly, either every day or every week.
- Thomas G. Lechler and others (2005) look at how the CC method is used to run projects. In their study, they compared and analysed CC and CPM in different ways to find out how they were different. Ronen and Starr (1990) looked at a few other issues and the main difference between Just-In-Time (JIT) and Optimised Production Technology (OPT) management on a scholarly and strategic level. Their evaluation of CO and CC was done on both a scholarly and a strategic level. Also, the paper shows how CC and CP approaches are different in terms of their ideas. It was decided that CP is a tried-and-true method, while CC moves the project along more quickly but requires a lot of investment in terms of training and framework. To switch to a CC point of view, this investment must be made.
- Oya I. Tukel et al. (2006), the authors described two ways to figure out the size of feeding buffers when making schedules using the critical chain approach. With the proposed methods, project features are built into the formation. One of the strategies uses resource tightness, while the other uses network complexity. The authors tried to work the CC idea into the resource-constraints project in their study, which could be looked at again for more scheduling research. The paper was tested and compared using two similar ways to manage buffers: the cut-and-paste method and the root-square-error method. No buffer was used as a benchmark. The simulation study used the PDS to do the collation. The authors talked about the Adaptive Buffer Sizing methods (APD), which were meant to generate buffer sizes and make it more likely that a project would be finished on time.
- Behzad Ashtiani et al. (2007) talk about how to use the lognormal distribution to figure out how long it will take to finish a task and how to take into account the risk of the task to figure out the distribution's parameters. Root Square Error Method (RSEM) was used to come up with a new way to figure out how big the buffer should be. For the simulation study, the lengths of time given in the data set were used to find the median time and the scale parameter for each activity. Lognormal distribution was used for the time it took to finish each task, and a new analysis was given to figure out the size and shape parameters for each task. More research was done to find out how other statistics for the time it takes to finish a task are spread out. All of the tasks in the project distributions must meet the main requirements for how long they take to finish. This study was also meant to find new parameters that will be used to figure out deviation activities.

III PROJECT IDENTIFICATION AND FORMULATION

Directly or indirectly, a project in economic terms contributes to the country’s economy. However, introspection into the performance of the project clearly indicates that the situation is not satisfactory. Large and important public sector projects such as irrigation, agriculture and infrastructure are also suffering with enormous time and expense. Performance in the private sector is also unsatisfactory due to growing illness in the industry and a significant increase in the non-performing assets (NPAs) of banks and financial institutions. There are a lot of reasons to run over time and cost and they can be broadly classified under technical, financial, procedural and administrative. Most of these problems arise from inadequate project structure and random implementation.

Project Identification

Project identification is an important step in project construction. They conceive to meet market demand, exploit natural resources or create wealth. Project ideas for development projects mainly come from the national planning process, while industrial projects generally arise from the identification of commercial opportunities and profitability.

Since projects are a tool to achieve certain goals, there can be many alternative projects that can serve these goals. It is important to point out all other options that are considered justified in favor of the specific project proposed for consideration. Field studies, Opportunity Studies, Supporting Studies, Project Identification Focuses on the number of project ideas tested based on available information and data and expert opinion and hopefully comes up with a limited number of project options.

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Project Formulation

"Project formulation" is the process of presenting a project idea in one form, subject to comparative evaluation with the intention of determining exactly what is the priority associated with a project under multiple resource constraints. The following steps.

PROJECT FORMULATION

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OPPORTUNITY STUDIES/SUPPORT STUDIES

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IDENTIFICATION OF PRODUCT/SERVICE

↓

PREFEASIBILITY STUDY

↓

FEASIBILITY STUDY (TECHNO ECONOMIC FEASIBILITY)

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PROJECT APPRAISAL

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DETAILED PROJECT REPORT

Figure: Project Formulation –Schematic view

PROJECT MANAGEMENT TECHNIQUES

MANAGEMENT METHODS

With traditional project management methods, 30% of the lost time and resources are typically consumed by wasteful techniques such as bad multi-tasking, Student syndrome, In-box delays, and lack of prioritization. In project management, the critical chain 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. If resources are always available in unlimited quantities, then a project’s critical chain is identical to its critical path.

Critical chain is used as an alternative to critical path analysis. The main features that distinguish the critical chain from the critical path are:

- The use of (often implicit) resource dependencies. Implicit means that they are not included in the project network but have to be identified by looking at the resource requirements.
- Lack of search for an optimum solution. This means that a “good enough” solution is enough because:

1. As far as is known, there is no analytical method of finding an absolute optimum (i.e. having the overall shortest critical chain).
2. The inherent uncertainty in estimates is much greater than the difference between the optimum and near-optimum (“good enough” solutions).

- The identification and insertion of buffers:

1. project buffer
2. feeding buffers
3. Resource buffers. (Most of the time it is observed that companies are reluctant to give more resources)

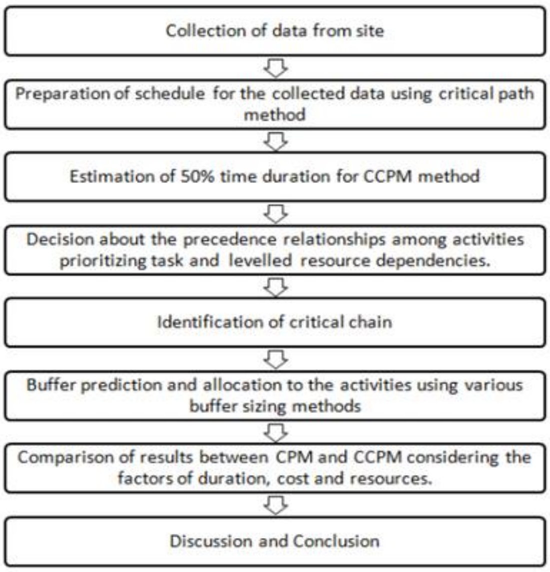
- Monitoring project progress and health by monitoring the consumption rate of the buffers rather than individual task performance to schedule.

CCPM planning aggregates the large amounts of safety time added to tasks within a project into the buffers in order to protect due-date performance, and to avoid wasting this safety time through bad multitasking, student syndrome, Parkinson’s Law and poorly synchronized integration.

Critical chain project management uses buffer management instead of earned value management to assess the performance of a project. Some project managers feel that the earned value management technique is misleading, because it does not distinguish progress on the project constraint (i.e. on the critical chain) from progress on non-constraints (i.e. on other paths). Event chain methodology can be used to determine a size of project, feeding, and resource buffers.

IV CRITICAL CHAIN MANAGEMENT IN CONSTRUCTION PROJECTS

The work compares CCPM method and the traditional CPM through a case study of construction of a residential building. The data is collected from a real-life project. The MS-Project software is used as a scheduling tool in the project.



According to the PMI, the scope statement should include the following:

- Description of the scope
- Product acceptance criteria
- Project deliverables
- Project exclusions
- Project constraints
- Project assumptions

BUFFER SIZING METHODS

- In critical chain project management method, the safety times are given in the name of buffers and there are different types of buffers used such as project buffer, feeding buffer(s) and resource buffers which were discussed earlier. The buffers are sized using the following four types of buffer sizing methods.

1. cut and paste method
2. Root squares error method
3. Adaptive procedure with resource tightness
4. Adaptive procedure with density

CUT AND PASTE METHOD (C&PM)

This is the first proposed buffer sizing method by Eliyahu M. Goldratt in his book 'Critical chain' in the year 1997 which is the simplest of all the buffer sizing methods. It was named later as 'Cut and paste method' or '50% of the chain method' by other authors. Here, the project buffer size is equal to half of the duration of the critical chain and the feeding buffer size is equal to half of the duration of the feeding or non-critical chains. Although this sizing method is very easy to calculate, it has limitations such as negligence of uncertainties present in the activities and also activities with long durations produce large buffers which ultimately lack optimization in buffer sizing in this method.

Project buffer = 52.5/2 =26.25 days
Feeding buffer1 = 4.75 days
Feeding buffer2 =3.25 days
Feeding buffer3 = 1.75 days
Feeding buffer4 = 3.75 days
Feeding buffer5 = 2.5 days

ROOT SQUARED ERROR METHOD (RSQ)

In this buffer sizing method, rather than using a simple thumb rule as in cut and paste method, it sizes buffers as the square root of the sum of the squares of the difference between original duration and the aggressive duration for each activity along the chain. It is somewhat better than cut and paste method, but this method associates with limitation that the probability of duration is greater than 90% that probably undersize the buffers than required for the critical chains.

Project buffer = 17.87 days
Feeding buffer1 = 5.94 days
Feeding buffer2 = 6.5 days
Feeding buffer3 = 3.5 days
Feeding buffer4 = 7.5 days
Feeding buffer5 = 5 days

But for non-critical chains the feeding buffer is correspondingly increasing for lengthy chains, say for example in the above case
feeding buffer 2 =6.5days and
feeding buffer 4 = 7.5days

ADAPTIVE PROCEDURE WITH RESOURCE TIGHTNESS (APRT)

The buffer size in this sizing method is given as a product of a scaling factor 'K' based on resource compression rate and the standard deviation of the activities proceeding the buffer. Buffer size = K x σ
Where K = (resource usage / resource availability)
Here, the central limit theorem is applied in the calculation of standard deviation of the chain, which highlights that the average duration of the path is equal to the sum of the average durations of the tasks which makes the chain. Also, the variation in the chain is equal to the sum of variations of the activities forming the chain. The

square root of the variance gives the value of standard deviation.
Project buffer = 71.85 days
Feeding buffer1 = 1.25 days
Feeding buffer2 = 1.625 days
Feeding buffer3 = 1.4 day
Feeding buffer4 = 1.875 days
Feeding buffer5 = 1.25 days

ADAPTIVE PROCEDURE WITH DENSITY (APD)

This buffer sizing method suggests the concept that when the number of precedence relationships among the activities increases then simultaneously the delays in the project also get increase (i.e.) the interdependence between the tasks is directly proportional to the delays occur in the project. The density of the project is nothing but the number of precedence relationships in the project. The significant factor in the buffer sizing method is the term 'density'. Also the buffer size depends on a scaling factor 'K' which is set as one plus the ratio of total number of precedence relationships of the particular chain to the total number of tasks originally present in the same chain. The buffer size is the product of scaling factor 'K' and standard deviation of the activities preceding the chain.

Buffer size = K x σ
Where K=1+ (number of precedence relationships/total number of tasks)
Project buffer = 19.89 days
Feeding buffer1 = 2.09 days
Feeding buffer2 = 1.625 days
Feeding buffer3 = 0.875 day
Feeding buffer4 = 1.875 days
Feeding buffer5 = 1.25 days

MONITORING AND MANAGEMENT OF BUFFERS

In CCPM method, the project is not monitored according to its completion date instead it is monitored based on the rate of consumption of buffers by the activities. The below are the three steps to be followed in buffer management on a periodic basis.

1. The size of the buffers should be adequately and appropriately arrived using efficient buffer sizing methods.

2. Buffer consumption rate should be predicted on a regular basis for the smooth progress of the project.

V CONCLUSIONS

Managing projects in multi-project environment are mainly activities focused on synchronizing the use of critical resources while timing projects. At the level of the programme or projects portfolio the critical chain method in projects planning proves its usefulness primarily due to a systematic approach to the identification and planning of the use of critical resources in time while taking into account the strategic priorities of project organization. Barriers resulting from construction practice for using CCMPM in managing of construction projects portfolios are mainly connected with decision-making limitations concerning due dates of starting the projects that in construction companies are carried out as part of the stock of orders for which investors determine the time frames in individual contracts for construction works. In the case study, a similar barrier stemmed from the conditions related to external financing – financing agreement stipulated the necessity of executing individual projects included in the programme in accordance with schedule, which is an integral part of this agreement. The event of default could result in funding loss. In contrast, if the condition of proper programme implementation would be the deadline for programme completion as a whole, the planning based on CCMPM would allow flexible scheduling of individual projects and their movement within the limits designated by capacity constraint buffers. In this way, from the perspective of portfolio, management would be improved first and foremost with a contract for investor's supervision and reduction of negative multitasking of critical resources. To verify the effectiveness of the use of CCMPM in managing multiple construction projects, it is advisable to conduct further analysis, mainly from the perspective of projects portfolio carried out within a specified time by construction company, on the basis of a set of contracts and schedules of various structures.

It is experimentally observed that CCPM works better than traditional methods. Project completion date is prevented from uncertainties because of the use of fever charts as it helps the managers to take protective actions against delays. It is known from literature reviews that CCPM has been extensively used in software and production firms. It is also recommended to the construction sectors to get benefit from CCPM approach. It is clearly shown that the project might surely completed on-time as scheduled and also within the allotted budget as because the leveling and balancing of resources are done in CCPM before assigning precedence relationships among the activities, which paves way for the elimination of idling of resources. The following advantages are noticed with CCPM method.

1. It accumulates all safety buffers at the end of the project instead of providing them into each activity, and protects the critical chain against insecurity.
2. It focuses on the project constraint (the longest chain of dependent resources or activities).
3. Uses average-case estimates (task estimates based on 50% probability of completion.
4. Starts tasks as soon as predecessors are done, finishes tasks as quickly as Possible
5. Avoidance of Student's syndrome, Parkinson's law, Murphy's law, and Multitasking
6. Relay race Scheduling and Late start Scheduling of Non-critical activities.

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