Kalpa Publications in Civil Engineering
Volume 1, 2017, Pages 291–300
ICRISET2017. International Conference on Research and Innovations in Science, Engineering &Technology. Selected papers in Civil Engineering

Buffer Based CCPM Scheduling: A Modern Approach for Indian Constraints

Mona P. Prajapati [1*] and Neetu B. Yadav [1†]
[1] S.N.P.I.T. & R.C., Umrakh, Bardoli, India.
pmp7001@gmail.com , n.neetuyadav@yahoo.com

Abstract

At present in Indian Construction, large number of construction projects is delayed by many reasons one of them is 'improper planning and scheduling' and 'resources uncertainty', which are more concerned for every project manager. There are many scheduling techniques but resource based technique is only one i.e. Critical chain project management (CCPM). This paper contains review of 35 research papers, thesis and articles on CCPM. Main aim of paper is to explore the opportunities to apply CCPM by means of literature review to minimize uncertainty and variation in project activity duration. Paper also describe theories behind CCPM network and procedure of preparing CCPM network.

1 Introduction

The construction sector in India is major contributor to the Indian GDP. But delay in construction projects lead to both cost and time overrun and resulted in loss to stakeholders. Indian construction industry presently used many scheduling techniques but they are mostly task based there is less use of resource based scheduling techniques. Even though construction sector using scheduling techniques all the project might not be completed on time due to various uncertainty that are not concerned while scheduling, to overcome that effect CCPM is one of the best tool to complete the project in frame of time. It also facilitate in reducing extra safety time that added into each and every activity and instead of that it will use buffers for maintaining project according to time.

Dr. Eliyahu Goldratt introduced the new concept of scheduling the project, which is known as Critical Chain Project Management in 1997 to overcome the drawbacks of traditional scheduling techniques. He published book on title 'Critical Chain' in 1997. This book introduces concept of Theory of Constraints (TOC), which is used in CCPM technique (Ghaffari & Emsley, 2015, pp. 43-54). According to PMBOK, "Critical chain method is a schedule network analysis technique that modifies the project schedule to account for limited resources" (Chawan, Gaikwad, & Gosavi, 2012,

[*] Student of Master of Engineering in Construction Engineering and Management.
[†] Assistant Professor in Civil Engineering Department.

C.D. Modhera, G.J. Joshi, D. Soni, I.N. Patel, A.K. Verma, L.B. Zala, S.D. Dhiman, D.R. Bhatt, J.M. Rathod, B.C. Goradiya, M.S. Holia and D.K. Patel (eds.), ICRISET2017 (Kalpa Publications in Civil Engineering, vol. 1), pp. 291–300

pp. 1048-1052). Therefore, CCPM is a method that emphasizes on resources i.e. work force, equipment, space and materials to execute project tasks.

Buffer helps to reach up to 50% probability of being completion on time at the end of activity with uncertainty allowance. CCPM deal with two major challenges namely buffer size and multiple resource levelling.

Countries like Romania, Japan, Australia etc., which have already implemented the critical chain concept in their construction industries, India is still continuing with the conventional methods. Rudolf G. Burkhard has conducted study on, "Critical Chain in Japan: Disasters – Rapid Response, Rapid Repairs" in year 2014. He describes in this article, how the Japanese deled with a disaster more quickly and effectively – by using Critical Chain Project Management. In fact Japanese government require CCPM schedule before passing large infrastructure projects in Japan which shows positive effect of CCPM than any other network (Burkhrad, 2014).

2 Theoretical Background of CCPM

2.1 General

Critical Chain Project Management approach originated to understand basic ideas. This approach is commonly used to get answers of two basic questions, 1) how to priorities activity and resources and 2) how to deal with uncertainty. The first question is answered by Theory of Constraints and other by statistical control concept of common cause variations. i.e. statistical laws governing the common cause variation (Chawan, Gaikwad, & Gosavi, 2012).

Author name	Work done in CCPM	Year
Dr. Eliyahu M. Goldratt	First introduction of CCPM as well as concept of CCPM was given.	At International Jonah Conference in 1990
Dr. Eliyahu M. Goldratt	Business novel on 'Critical Chain' that explain principles of TOC and give 50% buffer sizing rule.	1997.
Leach	Theory of CCPM and detail practice of CCPM.	1999
The Product Development Institute	Introduced RSEM for buffer sizing.	1999
Graham K. Rand et al.	Introduced interlinks and inter connectivity between CPM & CCPM.	2000
Herman Steyn	Derived how TOC helps in project scheduling using CCPM.	2002
Wei, Liu, and Tsai	Compared and derived the advantages and disadvantages of traditional method and TOC based method.	2002
Dr. Eliyahu M. Goldratt	Give TOC Insight project management programme.	2003
Leach	Introduces BPRSEM for buffer sizing.	2003
Leach	Introduce real and practical approach for continuous improvement of CCPM.	2004
Herroelen and Leus	Gave stochastic resource constrained project scheduling	2005
Thomas G.	Find that number of TOC ideas that can be used	2005

Lechler et al.	without implementing the whole concept of CC and benefited the project.	
Shixin et al.	Presented a model of CCM considered work in process for product plan.	2006
Rabbani et al.	Presented project-scheduling method by resource constraints for merging new and traditional resource management method by stochastic network.	2007
Ashtiani et al.	Introduced High Confidence RSEM.	2007
Tenera et. al.	Give highly sophisticated approaches using Computerized simulations.	2007
Ohsato	Fuzzy CCPM based scheduling developed.	2008
Huang	Explored the due-date performance problem using the concept of the aggregated time buffer in CCPM.	2009
Realization: A leading CCPM provider	Concerto CCPM Software and case study.	2009
Zhen Yu Zhao	He proposes an innovative critical chain method (ICCM) for project planning and control under resource constraints and uncertainty with an improved genetic algorithm.	2010
Xue-mei et al.	Introduced Improved RSEM.	2010
Srijit Sarkar	He prepared CCPM as well as CPM using MS Project –a project management software and compared both networks.	2012
Kaushik M.	CCPM implementation related potential barriers were identified for Indian construction industry.	2013
Yang and Fu	Activity priority based multi project scheduling method introduced.	2013
Repp & Wright	They done identification of CCPM success factors.	2013
Guofeng Ma et al.	CCPM framework to enhance the capabilities for project management practice.	2014
Guofeng Ma et al.	Proposed Scenario-Based Proactive Robust Optimization for CCPM Scheduling.	2015
Mahdi Ghaffari	Suggest current status of research on CCPM approach from literature study as well as list of topics in CCPM that are still required research.	2015
M. Poshdar et.al.	He discusses a probabilistic-based buffer allocation method (PBAL), which enables the final decision on buffer size to be made by the project planners based on their preferences about project completion time.	2016

Table 1: Past work carried out on CCPM

2.2 Theory of Constraints (TOC)

The bottom line of Theory of Constraints is that 'In every system there must exist a constraint on the output'. Theory of Constraints can be applied as per following steps (Rand, 2000):

1) Identification of the system's constraint
2) Exploitation of the constraint
3) Subordinate everything else to the constraint
4) Elevation of the constraint
5) If the constraint is broken, go back to Step 1

2.3 Common Cause Variation

According to Dr. W. Edwards Deming, Common Cause is a cause that is inherent in the system. The responsibility of management. Project scheduling and control should handle it. Now, to protect project against common cause variations of activity durations, it can be gained by closely chaining activities according to activity dependencies and resource constraints.

2.4 Statistical Laws Governing Common Cause Variation

The statistical law method is to combine variances that we can protect a chain of activities to the same level of probability with much less total contingency time than that we can protect each individual activity. Aggregation of the contingency times dramatically reduces the overall estimated time for a chain of activities. This aggregating activity follow the central limit theorem. The central limit theorem states, "As sample size increase, the distribution of the sample mean becomes closer to the normal distribution."

3 Buffer

Buffer is an extension of the task time for natural calamity or uncertainty. In traditional scheduling techniques, safety time was added into all individual activities so it resulted in longer project duration, which is unnecessary. So to reduced that safety time and reduce overall project completion date CCPM uses buffers instead of safety time that are added at the end of network. There are mainly three buffers i.e. Project buffer, Feeding buffer and Resource buffer (D. Pragadeesh Kumar & Vasan, 2016). Project buffer inserted at end of scheduling network of project to protect the completion date. Feeding buffer protect the critical chain from late finishes of the non-critical preceding activities that required to be completed before starting of successor critical activity. Resource buffer only give list of critical resources. It neither consume time nor consume cost of the project.

CCPM application year	Project data
In a conference in May 1998 at Goldratt Institute and presented by Philip Baylis	Balfour Beatty Civil Engineering Ltd.
From year 1999 At NASA	In Langley Research Center
November 2006 By Yuji Kishira (as advisor and consultant) and Japanese government.	Miyazaki-City-Project
Published in implementation	Synergies Technologies Group: They concurrently manage over 200 projects with each project having over 150 tasks using CCPM.
Guide of CCPM by Goldratt in 2007.	Romanian construction industry

Start using CCPM after 2009.	Brazil aircraft company
Since 2010	Case company
Started using CCPM from July 2010 By Chia-Ling HUANG	Texas Instruments, Lucent Technologies, Honey-well, and
After 2012.	Harris Semiconductor
Located in Wellington City in e New Zealand in 2013	construction project which aimed at seismic strengthening of an existing building in anticipation of future seismic activity
In India 2014	Construction of multi storied residential building project case study.
In 2014	Infrastructure project in mid-sized city in China
In March 2014	Construction of silos for Ultra tech. company scheduling done by L & T InfoTech. At Haryana in India.

Table 2: Details of Projects/ Company applied CCPM network technique

Buffer calculation is done using mainly two methods. 1. Cut and Paste method (C & PM) and 2.Root Square Error Method (RSEM).

3.1 Formula of C & PM given by (Sarkar, 2012) is:

$$Buffer\ size = \frac{Sum\ of\ Safety\ time\ remaing\ after\ computing\ 50\ \%\ probability\ network}{2}$$

3.2 Formula of Root Square Error Method (RSEM) given by (Sarkar, 2012) is :

$$U_i = S_i - A_i$$

Where, U_i is the Uncertainty of task 'i',
S_i is the safe estimate of task 'i',
A_i is the average duration estimate of task 'i'.

$$\text{Buffer size} = \sqrt{\left[\sum (U_i)^2\right]}$$

4 Major Drawbacks of Traditional Method

In India construction firms uses various scheduling techniques as well as scheduling software but they still has some major drawbacks that frequently noticed while execution stage are (Sarkar, 2012):

- Student Syndrome: It means that worker tendency to do work on last mint as like students.
- Parkinson's Law: In that, work will expand to fill the available time of completion of task or project.

- Murphy's Law: The perception that -anything that can go wrong will go wrong totally.
- Multi-tasking: The problem of assigning multiple tasks to the same resource is major problem.

Subject	Bar chart method	CPM	CCPM
Design of schedule based on	Major activity based	Task based	Resource based
Time required for preparing schedule	For small requires less time but for large project very time consuming method	Less time for both small as well as large project	First time required more time than CPM after that less time require for scheduling.
Probability of project completion using schedule.	Schedules 99% probability task duration.	Schedules 95% probability task durations.	Schedules 50% probability task durations.
Location of safety time	All bars contains safety time.	Protects individual tasks with safety time.	Protects overall project completion with buffers.
Focus on	Emphasizes individual bar of activity.	Emphasizes task progress.	Emphasizes project progress.
Schedule type	Bars start and end defines activities start and finish time.	Stick to schedule dates for starting.	Starts tasks as soon as Predecessors are done, finishes tasks as quickly as possible.
Linking of activities	Not well defined	Properly shown but change sometimes while rescheduling.	Properly shown for whole project.
Multitasking	Shows multitasking in schedule.	Makes multitasking in project.	Minimizes multitasking by setting priorities almost reduce.
Minimizing Uncertainty	Not useful when there are uncertainty.	Reacts to uncertainty by deviating from critical path.	Manages uncertainty by Monitoring impact of events on buffer consumption.
Feasibility of Multiple project management	Not feasible.	Not much effective	Effective for multiple project management at same time.
Cost of software	Very low	Higher than bar chart	Higher than both other methods.
Track project progress	Not properly shown.	Done but not very effectively shown.	Very effectively shown.
Chances of	Very high.	Higher than CCPM and	Very less or no

delay		lower than bar chart.	delay occur.

Table 3: Comparison between Bar chart, CPM & CCPM

5 Steps for design of CCPM schedule

The following steps are used in developing critical chain project management schedule of the project:

1. Calculate quantity of various materials that are used in construction of project and find resources required to execute the project with the help of SOR.
2. Calculate the 50% duration estimate of all the tasks and then identify the primary resource constraints in the project.
3. Now, identify the resource conflicts and father steps to resolve them. For that start with the task that is closest to the project completion date or with the task that shows most resource conflict.
4. After all the resource conflicts have been ended, identify the critical chain as the longest chain of dependent events.
5. Insert the Project Buffer at the end of the critical chain.
6. Add Feeding Buffers wherever non-critical chain tasks try to feed into the Critical Chain.
7. Time constraints, especially in the case of tasks having no predecessors, should be adjusted to “as late as possible” to avoid bad multi-tasking within project.
8. Make use of buffer management to control the plan and track the project progress.

6 Advantages of CCPM

1. It will be resulted into faster completion of projects than any other scheduling techniques.
2. It will ensure elimination of multi-tasking within the given project.
3. It is flexible than the traditional method.
4. As it, consider human behavior during scheduling so improving workers attitude within project environment.
5. It is based on resource dependencies to ensure that non-critical tasks will not become critical in future, that mainly happen in traditional method due to avoidance of resources required for project.
6. It will provide very simple way of tracking and monitoring project progress with the use of graph.

7 CCPM Software

There are many software for project scheduling. Some of them also support CCPM scheduling techniques and recently more in use are as follows:

- MS Project
- Primavera

- ProchainTM
- LYNX Scheduler
- ConcertoTM
- Project Scheduler 8TM

Here, MS Project and Primavera are helpful in designing traditional schedule, which is then converted into CCPM schedule with the use of other listed softwares.

8 Tracking of CCPM schedule

In CCPM, scheduling tracking of project progress is done with the use of graphical method. In this method, whole graph is divided into three zones i.e. green, yellow and red. It describes in fig. 1 as below (D. Pragadeesh Kumar & Vasan, 2016),

- If project is in green zone, the project is under control. Not concern to project manager.
- If project is in yellow zone, the project is under control but the manager should look for the issue or conflicts that may cause the delay on later schedule.
- If project is in red zone means, the project is not under control and some necessary steps are required to be taken to bring back the project as per schedule.

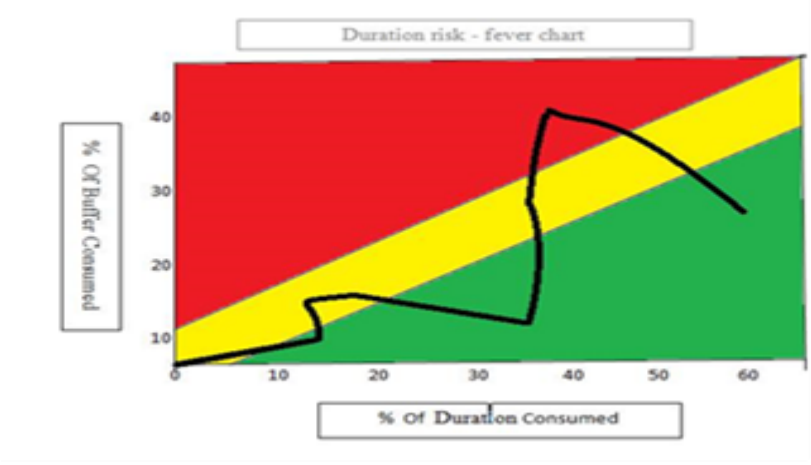

Figure 1: Duration risk chart used in CCPM tracking
(Source: Paper of "Developing an Appropriate Critical Chain Project Management System to MRTS Elevated Station Platform Structure at Adampakkam" by D.Pragadeesh Kumar et al. in year 2016.)

9 Conclusion

From this paper, we can say that instead of using task based scheduling it will be more fruitful to apply resource-based approach for project schedule. We have presented a brief review of CCPM from where it was started and today many countries are taking its advantage. The country, which strictly implemented the approach to get better results, is, the Japanese who use Critical Chain project management (CCPM), to control the vast majority of their infrastructure projects. Local governments

prefer contractors who use Critical Chain to manage and control the vast majority of their infrastructure projects.

Acknowledgment

I wish to express my deepest gratitude and sincere appreciation to Mrs. Neetu B. Yadav (Prof., Civil Engineering Department, S.N.P.I.T. & R.C., Umrakh) for her constant guidance, dedication and encouragement throughout the course of the study. I express our sincere thanks to Dr. N. D. Sharma (Principal and H.O.D, Civil Engineering Department, S.N.P.I.T & R.C, Umrakh) and all other faculty members of Civil department, S.N.P.I.T & R.C, Umrakh. I would also like to thank God, my loving parents, family and friends for their valuable support.

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