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TO STUDY THE IMPLEMENTATION OF CRITICAL CHAIN PROJECT MANAGEMENT IN CONSTRUCTION INDUSTRY

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ABSTRACT: Construction industry in India is the 2nd largest industry after agriculture industry. Almost 16% of the India's population are directly or indirectly dependent on construction sector. But here the main thing is more than half of the projects do not get completed within the given duration. The limitations of traditional project management methods are Student Syndrome, Parkinson's law and bad multitasking which increases the project duration. This paper compares the traditional method Critical Path method (CPM) with Critical Chain Project Management (CCPM). Eliyahu Goldratt 1997 suggested CCPM as an attempt for minimizing project duration. In this paper the author analyze the principles of CCPM starting with a review of its key element: reduction of duration estimates; buffer management; task completion; progress measurement and priority setting. A real life case study of highway project is taken for the application of CCPM. Final solution shows that CCPM is simple and can be used for mega projects to generate a shorter time at low cost.

Key words: *CCPM, Buffer Management, Construction Industry, Human Behaviour, Highway construction, Scheduling.*

I. Introduction:

Construction industry in India is the 2nd largest industry after agriculture industry. Almost 16% of the nation's working population are dependent on the construction industry for their livelihood. But, here the main problem is more than half of the construction projects are not completed within the time because they are facing issues like Cost Overrun and Time Overrun. Major drawbacks were found with the traditional project management methods like Critical Path Method (CPM) and Program Evaluation Review Technique (PERT). In the traditional method more emphasis is given on project tasks rather than resources. The limitation in the traditional method encouraged people to develop a new scheduling method called Critical Chain Project Management (CCPM).

Critical Chain Project Management was developed by Eliayhu. M. Goldratt. Since it's inception in 1997, it has been a major breakthrough in the field of project management. CCPM is a method of planning and managing uncertainties in the project that emphasizes resource to execute project task and it aims at delivering the project faster as compared to traditional CPM method and achieves it through the process of waste reduction without affecting the quality.

The first step for CCPM consists of developing an initial schedule for the project activities with their duration estimates. This is done while talking into account the dependencies among the activities is (as reflected in the project network) and the availability of resources. At this point CCPM identifies the "critical chain" as the set of activities that result in the longest path to project completion after resource levelling. The next step in CCPM planning consists of recalculating the project schedule based on shortened activity duration estimates. The rationale of CCPM for shortening the original duration estimates is as follows:-

A. Reduce individual activity estimates by 50 percent. The remaining 50% duration is used as Buffer.

B. Set Feeding buffer (FB) (half of the summation of non-critical chain activities buffers) at points where non-critical chain intersects the critical chain.

C. Set Project Buffer (PB) (half of the summation of critical chain activities buffers) at the end of critical chain.

II. LITERATURE REVIEW:

From the various literature review, the traditional method and the Critical Chain Project Management Method were studied in detail and both the methods were compared by applying them on a real life case study**.**

Larry Leach P et al. (1997) critical chain project management improves the project performance and explained critical chain project management which provides a important step in the continuous improvement to the project organization for managing projects+. By CCPM the project plan becomes better by making sure that it is possible and protected from sensible prevalent cause limits. It is done by combining uncertainty with buffers at the finish of the activity path. The project buffer protects the overall project completion on the critical chain path and feeding buffer protects the critical chain from path merging.

H Steyn et al. (2002) The author has mentioned various reasons for reducing the project duration. First reason being, human behaviour to provide considerable provisions for contingencies during project planning which further leads to overestimation. Secondly, multitasking by the worker leads to the negative effect on the project which should be avoided. Thirdly, CCPM provides the contingency reserves to whole of the project rather than to individual activity due to which project duration is affected.

Francosis Retief et al. (2002) Author states that the improving project performance can be attained by modification of team behaviour to reduce bad work habits and by using combine safety in the form of the buffers, and that protects the project finishing date. The paper also points the different ways due to which hold advance tasks that contains safety and people move forward to extravagantly for the available safety. The essential changes in CCPM as compared to CPM practices were mentioned which were reduction of activity times to 50%, the process of developing critical chain exploiting activity and resource logic, provision of the Various buffers to protect the critical chain from delays etc. All such essentials in CCPM lead to faster completion of a project.

Rob Newbold et al. (2010) the paper suggest that if a same type of resource is to be used for more than one activity at certain point of time, such activities should be scheduled at different points of time. The paper gives an idea about the use of fever charts, buffer penetration, and consumption of buffer which represent the status of the activities on the fever charts. The fever chart was divided into three zones viz Red Zone, Yellow Zone and Green Zone. The paper has given definitions of some important terms related to CCPM such a project buffers, iteration risk, fever chart, critical chain, buffer consumption.

THEORY OF CONSTRAINT

Theory of constraints (TOC) is the root of the critical chain project management method and the term was first coined and used by Eliyahu M. Goldratt in his book 'The Goal' in 1984. He first applied TOC to production system and it was later extended to the construction field. The basic concept of TOC is that there may be at least a single constraint available to each stage in a project and the performance of the project must be increased when those constraints are eliminated completely. Thus, significant measures are to be taken in optimizing the constraints of a project. To improve the outcome of the project, TOC focuses on the following five steps.

1. Identify the constraints.
2. Exploit the constraints.
3. Sub-ordinate everything else to the system.
4. Elevate the constraints.
5. Repeat the process from step 1, if there are further constraints in the system.

III. BUFFER MANAGEMENT:

TYPES OF BUFFER:

In CCPM method the safety time is given in the form of buffer. Three types of buffers are used in CCPM- Project Buffer, Feeding Buffer and Resource Buffer. These buffers act as a safeguard and they are placed at a key point in the project. The function of these buffers is to protect the tasks against statistical discrepancies and act as a cushion against overrunning tasks, without affecting the project completion date.

Project Buffer: This is inserted after the last task in the critical chain.
Feeding Buffer: This buffer is inserted at places where the non-critical tasks feed into the Critical Chain.
Resource Buffer: This buffer is placed at whenever a particular resource has a job on the critical chain. Resource buffers indicate that that resource are available whenever needed.

BUFFER SIZING

The buffers are sized using the following four types of buffer sizing method. They are;

1. Cut and Paste method
2. Root square error method.
3. Adaptive procedure with resource tightness.
4. Adaptive procedure with density.

This study is limited to the most common buffer sizing methods i.e. cut and paste method and root square error method.

CUT AND PASTE METHOD

This is the first and most simplified method proposed by Eliyahu M. Goldratt and it has been named later as 50% of the chain method or the “cut and paste method”. In this method the buffer size is considered as half of the longest path in the chain.

Although this method is very easy to calculate, it has limitations such as activity with larger duration will lead to produce larger buffer which ultimately lack optimization in buffer sizing method.

Root square error method:

This method is introduced by Larry P. Leach (1999). This method provides much more efficient result but it is little more complicated.

In this buffer sizing method, it sizes buffer 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.

$$U_i = S_i - A_i ;$$

Where , U_i is the uncertainty of task $_{(i)}$, S_i is the safe estimate of the task and A_i is the aggressive duration estimate of task$_{(i)}$.

Therefore, Buffer size = $sq.rt[\sum(U_i)^2]$.

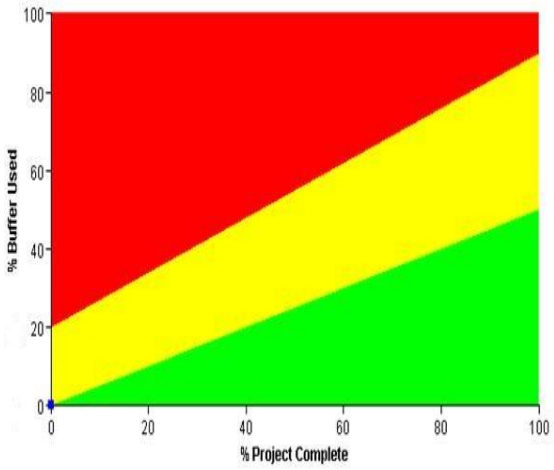
The main advantage of this method is that it generates buffer that are neither too long not too short in size.

Monitoring & 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.

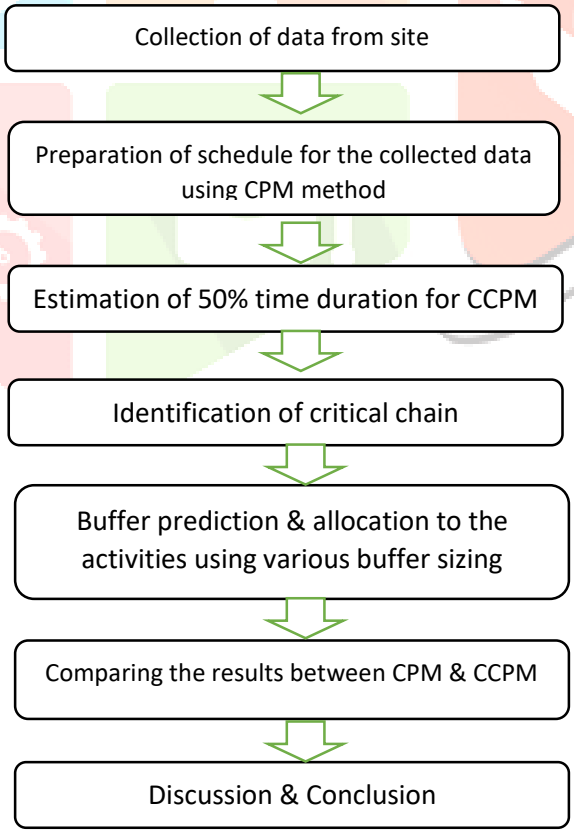
1. The size of the buffers should be adequately and appropriately arrived using efficient buffer sizing methods.
2. Buffer consumption rate should be predicted on a regular basis for the smooth progress of the project.

3. The above color-coded fever charts should be prepared which represent the risk-level in execution of the project through progress report according to which the buffers have to be managed on a weekly or monthly basis. The color-coded signals represent the following. Green zone = comfort zone – no action needed. Yellow zone = warning zone – The main cause of the delay should be identified and action plan is to be prepared.
Red zone = risky zone – The activities should be started right now and corrective actions must be taken immediately.



IV. Methodology:

This paper compares CCPM method and the traditional CPM through a case study of construction of a highway construction . The MS-Project software is used as a scheduling tool in the project.



VI. Case Study:

Case study from a real-time construction project was undertaken in this research work to validate the proposed CCPM framework and TOC characteristics. This section provides details of the case study and steps for implementing the framework.

Project description:

The case study was developed based on a highway infrastructure project executed in Gujarat state in India. A 2 kilometre stretch of the highway construction project was considered for developing the CCPM framework. The highway is the Ahmedabad-Viramgam-Maliya highway which is a part of state highway SH 17.

Typical overview of CPM:

The overview of the critical path method of scheduling is seen with a case study of a highway project. The original schedule of the project done by CPM using MS Project software is shown in figure.2.

	Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Construction of Ahmedabad-Viramgam_maliya Highway**	**65 days**	**Tue 01-12-20**	**Sat 13-02-21**	
2		Surveying	8 days	Tue 01-12-20	Wed 09-12-20	
3		leveling of bed by cutting and filling	3 days	Thu 10-12-20	Sat 12-12-20	2
4		Laying of borrow material	2 days	Mon 14-12-20	Tue 15-12-20	3
5		Preparation of Sub grade as per gradient	3 days	Wed 16-12-20	Fri 18-12-20	4
6		Watering and Compaction	2 days	Sat 19-12-20	Mon 21-12-20	5
7		Field testing FDD & OMC	2 days	Tue 22-12-20	Wed 23-12-20	6
8		Sub grade preparation (501 m - 1000)	4 days	Sat 19-12-20	Wed 23-12-20	5
9		Sub grade preparation (1001-1500)	4 days	Thu 24-12-20	Mon 28-12-20	8
10		Laying and grading of GSB first layer	4 days	Thu 24-12-20	Mon 28-12-20	7
11		Rolling of first layerd layer	3 days	Tue 29-12-20	Thu 31-12-20	10
12		Laying and grading of GSB second layer	3 days	Fri 01-01-21	Mon 04-01-21	11
13		Rolling of Second Layer	2 days	Tue 05-01-21	Wed 06-01-21	12
14		Field testing FDD & OMC	2 days	Thu 07-01-21	Fri 08-01-21	13
15		GSB preparation (501-1000)	2.5 days	Sat 09-01-21	Tue 12-01-21	14
16		WMM preparation (0-500)	3 days	Sat 09-01-21	Tue 12-01-21	14
17		GSB preparation (1001-1500)	3 days	Tue 12-01-21	Fri 15-01-21	15,9
18		WMM preparation (501-1000)	3 days	Wed 13-01-21	Fri 15-01-21	16
19		WMM preparation (1001-1500)	3 days	Sat 16-01-21	Tue 19-01-21	17,18
20		Kerb fitting (0-500)	2 days	Wed 13-01-21	Thu 14-01-21	16
21		Kerb fitting (501-1000)	2 days	Fri 15-01-21	Sat 16-01-21	20
22		kerb fitting (1001-1500)	2 days	Mon 18-01-21	Tue 19-01-21	21
23		Preparation of DBM layer (0-500)	6 days	Wed 13-01-21	Tue 19-01-21	16
24		Preparation of DBM layer (501-1000)	6 days	Sat 16-01-21	Fri 22-01-21	18
25		Preparation of B.C. (F.R.L) (0-500)	6 days	Wed 20-01-21	Tue 26-01-21	23
26		Preparation of B.C. (F.R.L) (501-1000)	6 days	Wed 27-01-21	Tue 02-02-21	24,25
27		Prepartion of D.B.M layer (1001-1500)	6 days	Wed 20-01-21	Tue 26-01-21	19
28		Preparation of B.C. (F.R.L) (1001-1500)	8 days	Wed 03-02-21	Thu 11-02-21	26,27
29		Tree plantation	2 days	Fri 12-02-21	Sat 13-02-21	22,28
30		Construction Complete	0 days	Sat 13-02-21	Sat 13-02-21	29

By CPM method, the total project duration taken to complete the project is 65 days**.** inter-dependencies among activities with the proper utilization of resources. Although CPM holds a particular position in project management, people' faith towards it is reducing day-by-day.

The loss of popularity in critical path method may be due to the following disadvantages.

1. Without understanding the ultimate aim of project completion, people tend to increase additional safety times to each individual task in CPM.

2. People only focus on task dependencies and resource dependencies are not given preference in critical path analysis.

3. Critical paths may change at any stage of the project and there may be more than one critical path which leads to confusion.

4. During Execution, there may be more chance of non-critical paths becoming critical path.

5. The basic assumptions in CPM are far beyond the practical scenario and the project team's prediction of scope is not under control.

Typical overview of CCPM

The following are the general steps followed in the critical chain project management technique.

1. The aggressive 50% time estimation is calculated for each for each activity.

2. Resources allocated separately to each activity and it must be levelled.

3. After Resource levelling, relationships between the activities are predicted incorporating both task dependencies and the leveled resources' dependencies.

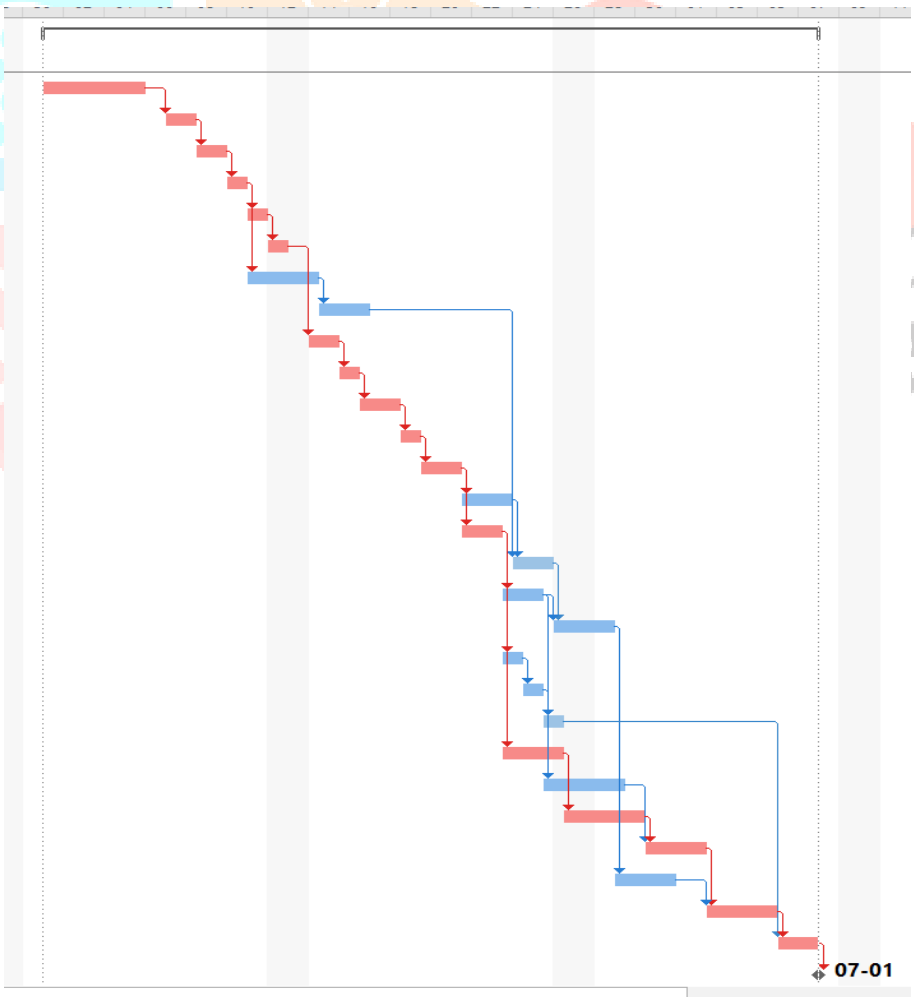
4. The longest path of the activities including both tasks and resources is identified as a critical chain.

5. Rescheduling of the project is done to ensure that the critical chain remains the same for the entire project.

6. The project buffer is inserted at the end of the critical chain and feeding buffers are inserted at the end of each non-critical chain to prevent non-critical chains becoming critical chains. The buffers are calculated using various Buffer-sizing methods and the methods are discussed in detail in the upcoming steps.

7. Buffer Monitoring and Buffer Management are the immediate steps to be undertaken after completion of the buffer insertion process.

8. Proper Buffer sizing and Buffer Management processes leads the project o complete earlier as scheduled also achieves good results in terms of cost performance of the project.



By using CCPM method, the project duration were reduced to 33 days. Here, the critical chain activities are (1-2-3-4-5-6-7-10-11-12-13-14-16-23-25-26-28-29) and non critical chain activities are (8-9-15-17-18-19-20-21-22-24-27). The project buffer is inserted after activity 29 and the feeding buffer 1 is inserted after activity 25 and feeding buffer 2 is inserted after activity 26.

Buffer sizing method

1. Cut & Paste method

Here, Project buffer is equal to half of the duration of the critical chain & feeding buffer is equal to half of the duration of the non critical chain. The detail overview about C&PM is provided in the buffer management section.

Project buffer = 17.25 days

Feeding buffer 1 = 3.75 days

Feeding buffer 2 = 7.5 days

2. Root square error method.

It sizes buffer 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.

- $\sqrt{(Si - Ai)^2}$

Project buffer = 8.91 days

Feeding buffer 1 = 3.4 days

Feeding buffer 2 = 4.94 days

SUMMARY:

Buffers	C&PM	RSQ
	(in days)	
Project buffer	17.27	8.91
Feeding buffer 1	3.75	3.4
Feeding buffer 2	7.5	4.94

Result:

The following table shows the total duration of CPM & CCPM method.

	CPM	CCPM	
Total project duration		C&PM	RSQ
	65 days	50 days	42 days

From this result, it is cleared that CCPM works better than CPM in terms of project duration. Root square error method of CCPM proves to be an effective method among the two methods because it gives the less duration of 42 days. In C&PM the project buffer and feeding buffer are divided into half of the length of critical and non critical path. If a activity has larger duration than it produces larger buffer which ultimately lacks optimization in buffer sizing method in C&PM

VII. CONCLUSION:

The traditional CPM technique faces a number of problems such as bad multitasking, Parkinson's Law, student's syndrome and deliberate padding. CCPM provides a substantial step in continuous improvement to the project management body of knowledge;.

CCPM focus for the whole project, the "Buffers" provide focus and obvious decision for the Project Manager. The essential changes introduced by CCPM relative to the current CPM practices are development of the critical chain using both activity logic and resource constraints, reduction of activity estimated duration and costs in some cases, using buffer management as the primary tool for project management and control. CCPM indetify project constraint in the initial stage which is avoided in CPM metnod. CCPM focuses on both critical and non critical activities.

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