Overview of Critical Chain Project Management In Construction Industry

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Abstract- *Construction Industry needs to adopt a new planning and schedule technique. This new techniques will deliver the project in much faster pace. Critical Chain Project Management (CCPM) is emerging from the last two decades. Here the paper deals with the basic concept of this method from planning stage to control stage. CCPM was developed on the principle of Theory of Constraint (TOC) where it said that each and every project have a constraint and needs to be eliminated to successfully complete the project. CCPM is task oriented and not an activity oriented. Main focus of this method is on the completion date and not on an activity completion. To complete the project on time, buffers will be placed. The main challenge to adopt this method is its buffer sizing. Proper buffer size must be calculated with Cut and Paste Method and Root Square Error Method. Another thing to consider while planning is to know the availability of resources on site as there will not be an unlimited supply of resources. Software will be used to schedule the project. This will help to monitor the project and take the corrective actions if necessary. Fever chart helps in monitoring project performance. India is a developing country and face many problems in constructions like cost and time overruns. So CCPM can be applied to Indian Construction Industry. Here the literature related to critical chain is been studied and view on the Indian Construction Industry is suggested.*

Keywords- Sizing, Critical Chain Project Management, Fever Chart, Theory of Constraints.

I. INTRODUCTION

With rapid increase in the demand of better infrastructure, one must be aware that construction of such an infrastructure requires huge amount. In order to deal with this, proper planning must be carried out with the help of new emerging techniques. In India, majority of the construction project are being scheduled using Critical Path Method (CPM) and Program Evaluation and Review Techniques (PERT). Focusing on the latest scheduling techniques Critical Chain Project Management in gaining fame from the last two decades.

Motive of introducing this techniques was to overcome the drawbacks of traditional scheduling techniques. According to the PMBOK, "Critical Chain method is a schedule network analysis techniques that modifies the project schedule to account the limited resources". Therefore, CCPM not only focus on the time estimates but also on the resources of the project which was overlooked in traditional method. Traditionally, projects were scheduled considering only the time estimates and resources availability was overlooked. CCPM will consider the time estimates but without the safety margin and consider the resources at the time of planning itself. To overcome the project from delays, buffers will be added at the end of project. This will help managers to keep track on the project.

To ease the work, construction industry have adopted the software like Primavera and MS Project for scheduling. Usually, MS Project is used by small and medium scale industries where large scale industries uses Primavera. This software will help to develop project plan, assign the resources and track the project. After feeding all the data Project Manager can easily know the Critical Path without additional computation.

II. HISTORY OF CCPM

Critical Chain Project Management (CCPM) is a method of planning and managing projects that can reduce project delivery time drastically. CCPM is based on methods derived from Eliyahu M. Goldratt's Theory of Constraints (TOC). It is a completely new thought process with emphasis on aggressive timelines for tasks, management of project buffer instead of task buffer and emphasis on resources to execute them. It can applied to single and multi-project environments that puts the main emphasis on the resources required to execute project tasks. Although, the significance of the well-known techniques, like PERT/CPM (Performance Evaluation Review Technique/ Critical Path Method), cannot be totally undermined, but the kind of revolutionary change.

The key features of Critical Chain Project Management are:

- Task times are reduced from conservative to realistic task estimates.
- Resource Conflicts are removed.
- Critical Chain is identified as the longest path considering both task logic and the resource contention.
- Project Buffer is placed at the end of the critical chain.
- Resource Buffers are also placed to ensure the availability of resources at right time in right quantity.
- Feeding buffers are placed at the joints where non-critical chains feed into the critical chain.
- Activities are started on 'As Late as Possible' philosophy after taking into account; the task logic, resource contention, and project completion time etc.
- Buffers are used as measures to control project performance.

All the above mentioned features differentiate it (CCPM) from other traditional project management techniques.

Critical Chain Project Management is the extension and the application of the Theory of Constraints to the practice of the project management. At its heart is the development of critical chain. Which is a sequence of activities that:

- Define the duration of the project.
- Includes both precedence and resource dependencies.
- Very rarely changes during the life of the project.

A central driver for adopting CCPM is enabling more predictable and shorter project lead times. The argument being that this will not only enhance time related order winning criteria but also reduce cost and improve adherence to specification. Finally Critical Chain can be defined as the longest sequence of resource leveled task that leads from the beginning to the end of the project**.** When we design CCPM solution we have to consider the following three aspects:

a) Mindset/Human elements
b) Planning
c) Control of the execution

Methodology of the Critical Chain identifies three negative factors of project management.

- Bad multitasking - more than one work is been done at a time.
- Student syndrome - work is been done at the last moment.
- Parkinson's Law - work expands to fill all of the time remaining before its completion. [1]

1.2.1 Types of Buffers:

Buffers used in CCPM are for the protection against the delay of project and to remove the resources contentions. There are usually three types of buffers which are placed at a strategic point in the network.

Project Buffer (PB): Safety time removed from the critical chain tasks will be summed up at end of critical chain. It is used to protect the project from fluctuation of critical chain. The additional time is there to protect the completion date of the project and hence it is called as a buffer. Refer Figure 1.

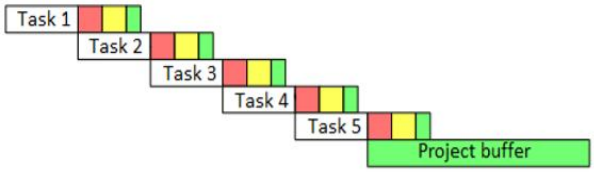

Figure 1 Buffer placed in the end of a chain protects her from delays.[2]

Feeding Buffer (FB): This type of time buffers are inserted at whenever the non-critical activities merges to critical activities and protects the critical chain from fluctuations. Main aim of this buffer is to protect the critical chain from unforeseen difficulties and disruptions on the non-critical tasks feeding it, and to allow critical chain tasks to start early in case things go well. When the project network consists of only one path, no feeding buffers are needed. There is a possibility that the insertion of a feeding buffer into a non-critical chain make the resulting feeding chain longer than the critical chain. This means that non-critical tasks have to be started before the first task on the critical chain or that time gaps need to be introduced into the critical chain of buffered baseline schedule. Refer Figure 2.

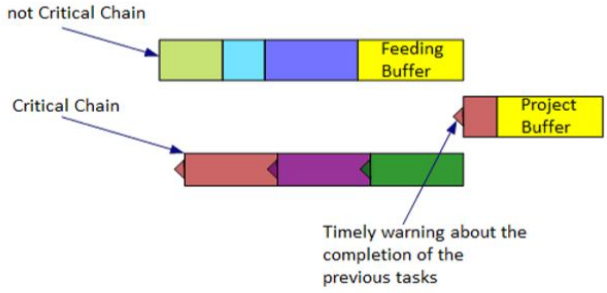

Figure 2 Feeding Buffer is placed on a non-critical Activity [2]

Resource Buffer (RB): Multiple artificial buffers that act as warning signals to assure the availability of resources. Resource buffers are placed whenever a resource has a job on the critical chain, and the previous critical chain activity is done by a different resource. Resourcebuffers should make sure that resources will be available when needed and critical chain tasks can start on time or (if possible) early. Resource buffers usually take the form of an advance warning, i.e. a wake-up call for every new instance of a resource on the critical chain. Alternatively, space (idle time) can be created on the resource to provide a kind of protective capacity. If such idle time is introduced to implement a resource buffer (possibly inducing additional resource conflicts and schedule distortion), the resource may well be invited to use its additional slack created on the predecessor activity which feeds the critical chain activity for which the resource buffer was inserted. A fundamental question to be asked is what needs to be done when more than one perfectly equivalent unit of a resource type may be allocated to a critical chain activity. [6]

1.2.2 Buffer Sizing Method:

There are two buffer sizing method which is usually used in the field and they are:

i. Cut & Paste Method:

In this method, safe estimates for each task is given. The critical chain and feeding chain will be calculated using 50% of the safe estimates as task duration. After the critical chain has been determined, the next step is to sum all of the safety time from the feeding chain and then take of this sim and use it as feeding buffer. The feeding buffer are added to the end of feedingchain where the feeding chain merges with the critical chain. [5]

ii. Root Square Error Method

Similar to the C&PM, this method uses two estimates for each task on the feeding chain. The safe estimate and the average estimate. Then the uncertainty of each task duration is calculated as

$$U_i = S_i - d_i,$$

Where $U_i$is the uncertainty of task i, S_i is the safe estimate and d_i is the average of 50% estimate of task i, for all i in the feeding chain. The buffer size is calculated as

$$\textit{Buffer size} = \textit{sqrt}\ (U_1^2 + U_2^2 + \cdots + U_n^2)$$

n= no. of activities in feeding chain.

It has been suggested that in cases where there are fewer than four tasks in the feeding chain, the feeding buffer should be least equal to the longest activity in that chain. Note that in cases where the feeding chain consists of one task, say j, then the buffer size is $(S_j - d_j)$. [5]

1.2.3Tracking of Project:

Each and every project has an official start and end dates. Starting of a project is usually called as a kickoff. This indicates the point in which tasks can start to be performed. After the kick-off, the project moves from the planning mode into the execution mode.

Now to track the project, buffers are divided in to three parts green, yellow and red. If the consumption of buffer lies in green zone, no need to take any action. If the consumption enters yellow zone, then a project management team needs to make corrective plan for future. And finally if the progress enters the red zone, the corrective plan comes into action to bring back the project to the green zone. Figure 3 show below three zones.

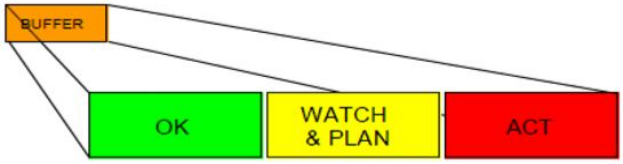

Figure 3: Buffer zones Green, Yellow and Red.

Each Buffer zones shall be divided into 1/3 of the buffer size. Green being the first zone, followed by yellow and red. Refer Figure 4

The tricolor graph is used to seen the project of the project. Graph is named as Fever Chart. The chart shows the percentage of buffer consumed vs. percentage of chain complete for a single or multiple project. Main purpose of fever chart is to quickly tell the project status to the project management team. Figure 5 shows the Fever chart for a single project.

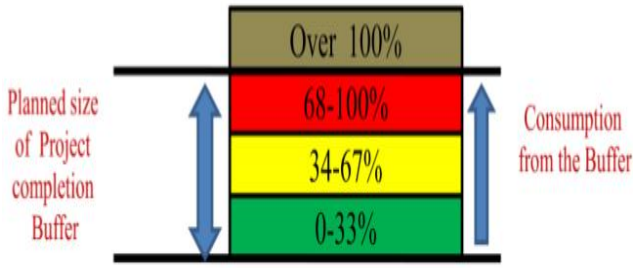

Figure 4: Buffer zones showing usage percentage

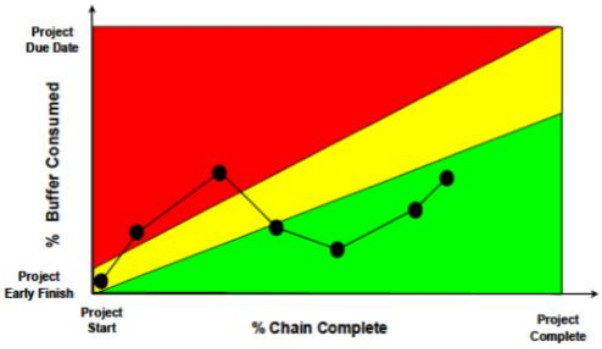

Figure 5: Measuring the trend of buffer consumption using Fever chart.

To calculate the buffer consumption rate and project progress, frequently reporting the Remaining Duration of each task is needed. Compared to the traditional project monitoring, this is a shift from focusing on percent of work (task) complete to focusing on how much time is left to accomplish unfinished (chain) tasks. This traditional manner of project control is subject to different interpretations. There is a human tendency to say that a task is 90% completed very quickly, and then spends just as long or longer finishing up the last 10%. Hence CCPM tracks progress through the team members estimates of remaining duration rather than work performed. A comparison of the remaining duration of a task with its original estimated duration is an effective measure of progress of the tasks on the chain. The buffer management reports the remaining duration of the project buffer as measurement of the project performance.

Tracking the project on fever chart needs the frequent calculation of percentage of chain complete and percentage of buffer consumption.

III. REVIEW

On the merits and pitfalls of critical chain scheduling (Willy Herroelen, RoelLeus), 2001.

This paper deals with merits and pitfalls of the critical chain scheduling and buffer management with has been emerged as a most popular approach by Goldratt in his book “Critical Chain” in 1997. Author highlights strength and weakness of CC/BM based on the critical analysis of the literature as well as of their own experience with commercial CC/BM software. Goldratt in his book said that time estimate must be taken at a 50% of the duration as it contain the safety margin but the author contradicts that statement and says that 50% rule for buffer sizing may lead to a serious overestimation of the required buffer protection. Computational experiments using Visual C++ was done to validate the fundamental working principles. 110 Patterson test problems are taken as part of experiment. Author concludes that CC/BM acted as an important eye-opener recognizing that interaction between activity durations, precedence relations, resource requirement and resource availability has a major influence on the duration of a project which in unrecognized by many practitioners. The CC/BM pitfalls resulting from this oversimplified view at the real scheduling and rescheduling issues have been scrutinized in this text and have been confirmed by a full factorial experiment. Using a clever project scheduling mechanism such as branch-and bound, has a beneficiary effect on the final makespan, the percentage deviation from the optimal final makespan obtainable if information would be perfect, and the work-in-process. Using the 50% rule for buffer sizing may lead to a serious overestimation of the required project buffer size. Regularly updating the baseline schedule has a strong beneficiary impact on the final project duration and provides better intermediate estimates of the final project makespan. Author says research on the development of effective and efficient algorithms for the creation of robust baseline schedules and powerful mechanism to warn project managers for upcoming problems is required.

An Investigation of buffer sizing techniques in critical chain scheduling (Oya I. Tukel, Walter O. Rom, Sandra DuniEksioglu), 2006.

Introduced two buffer sizing methods for determining feeding buffers sizes in critical chain method. Both the methods are than compared with the commonly suggested method. The new methods are incorporated with resources tightness and network complexity. Commonly used methods are cut and paste method and root square error method while author introduced methods are namely adaptive buffer sizing procedures and adaptive procedure with resource tightness. Patterson set is used for the simulation study to test both methods. Data sets consists of 110 projects with the number of activities ranging from 7 to 51 and using a maximum of three different types of resources. There are 8 projects with 22 or fewer activities, 10 projects with 51 activities and the rest being roughly equally divided in between 27 or 35 activities.

The data set also includes the minimum makespan, resources feasible, early start schedules. These schedules are determined assuming all task duration are known constants. Author concluded that they have evaluated the two new methods based on performance indicators: length of the planned completion times and probability of meeting the planned completion times. They have also mentioned earlier than necessary start time for tasks results in increase in work in process costs, whereas delays in project completion times result in penalties. Author says, extension of the above study must include other performance indicators such as cost. Another extension would be to allow rescheduling during the implementation of a project. Rescheduling at milestone may improve the project performance and help managers to complete the work within a planned duration.

Project buffer sizing of a critical chain based on comprehensive resource tightness (Junguang Zhang, Xiwei Song, Estrella Diaz), 2015

To understand the relationship between the activities and improve the accuracy of project buffer determination, buffer sizing method based on comprehensive resource tightness is been proposed. According to the law of diminishing marginal returns, physical resources tightness was initially determined by setting critical value of resource availability. The design structure matrix (DSM) is then adopted to analyze the information flow between activities and calculate the rework time resulting from the information interaction and the information resource tightness. Finally, the project buffer size is adjusted and determined by means of comprehensive resource tightness which consists of physical resource tightness and information resource tightness. Author achieves the objective by reaching the conclusion that the resource constraint between activities is the real reason affecting the independence of the activity time parameter, while network complexity does not affect the independence between activities. Author suggests that future researches must study the determination method and sequence optimization of the critical chain using DSM as a basis. Also complex factors based on DSM used to know the uncertainty of project duration. In all further focus must be on improving DSM.

Project management using the buffers of time and resources (Azar Izmailova, Diana Kornevab, ArtemKozhemiakin), 2016

Author studies the uncertainty of a project by implementing Critical Chain Project Management and comparing it with the traditional approach to project management. Data from the studies showed that 44 % of the project finishes on time and 70 % of the project reduce the amount of planned work. In today's world with new tools and techniques, number of project getting delayed should be decreased but the recent scenario tells us that, we at some point fall short and needs to work hard as a project manager. In this paper author explains the basic concept of CCPM which includes time estimates, types of buffers including resources buffers and one case with limited resource. He says that each task completion time is represented as a probability distribution and not as a constant. CCPM eliminates the drawbacks of the traditional project management like Parkinson's Law, Student Syndrome and Multitasking. Finally, author summed up the practical steps to use CCPM and convey that this will give company a new method to track a progress of project using time and resource buffers.

Effective Project Management with Theory of Constraints (Azar Izmailova , Diana Kornevab , ArtemKozhemiakin), 2016.

Critical Chain Project Management (CCPM) is a TOC tool used for planning and project management. It can be used both in one-project and multi-project structures where resources are being used in several projects simultaneously. For multi project structure, this tool includes all the elements of the same tool designated to be used in a one project structures, plus a tool to synchronize the implementation of projects. Author tells that there are different project types, but there are common questions for all project like project takes longer than planned, permanent budget overruns, payment not received in time, often resources are not available in time. Secondly, time planning of the project implementation is important aspect of CCPM. Project safety time planning needs a strict observation so that the extra time will not be wasted. The last key element of the Critical Chain methodology is about how buffers are used to make management decisions in the implementation of projects. If there are delays on the Critical Chain, than part of the safety buffer at the end of the project will be consumed. Watching the percentage of work performed on the Critical Chain and the percentage of buffer's time consumed, project managers can see the risks for all projects. When the two, buffer and Critical Chain, moving at the same speed, buffer is yellow, which is good. When the work is done at a faster pace than the buffer is consumed. Summing up all together author tells that, using this approach will complete more than 95 % of the project on time, project duration will be reduced by 20-25%. They achieve these results by synchronizing workflows through existing resources without adding people and investments in their systems. Reducing the duration of the projects means completion of more projects in the same amount of time. Although understanding this concept is easy but its implementation in

practice faces number of serious problems. Author says, senior management must be involved for implementing this method. Team must be aware about the concept of buffer insertion otherwise it will lead to the destruction of the buffer and unrealistic plans will be planned.

Application of Critical Chain Management in Construction Projects Schedules in a MultiProject Environment: a Case Study (Krystyna Araszkiewicz), 2017.

Krystyna Araszkiewicz in Application of Critical Chain Management in Construction Projects Schedules in a Multi-Project Environment: a Case Study said that, Multi project environment are mainly focused on synchronizing the use of critical resources while timing projects. In this paper author did a comparative analysis of Critical Chain Project Mangaement and Critical Path Method for the construction of several marinas in north western Poland. Techniques adopted for scheduling the project was critical chain method. As a part of the case study, a comparative analysis of the schedule prepared in the traditional method and in line with the assumptions of critical chain for an investment programme related to the construction of a network of port and marinas has been carried out. Author took 10 projects and planned them with CPM and CCPM. Each project was more than of 3 months duration with CPM method. Looking at the longest duration i.e. 496 days with CPM method came to 413 days in CCPM and project buffer of 135 days.Lastly, the author came up with a conclusion that, 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. 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.

IV. CONCLUSION

After review the literature it can be said that a CCPM is a technique which will allow project manager to complete the project before the schedule without allocating extra resources. It was also observed that buffer sizing method Cut and Paste method overestimates the project buffer and feeding buffer and another method must be used for largest projects. Further to that, many studies proved this on paper but actual implementation of CCPM is very rare. Indian construction industry needs to adopt this method and implement on site with strict observation to get the respective results.

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