CONSTRUCTION PROJECT BUFFER MANAGEMENT IN SCHEDULING PLANNING AND CONTROL

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Abstract:
In construction projects, one of the main problems in the schedule planning and control is the determination of the project schedule, especially, when the resources required are limited. Project managers or schedulers have used an estimated time to assure the completion time of either an activity or a project. However, this traditional schedule estimate, often fails in optimizing the project schedule performance, resulting in unnecessary time wastage. Dr. Goldratt proposed the Theory of Constraints (TOC) and Critical Chain, which provide the concepts for achieving effective activity duration control. Literatures show that the TOC and Critical Chain concepts are increasingly being accepted and applied in industries. The purpose of this study is to apply TOC and Critical Chain concepts in construction to manage buffers effectively in scheduling planning and control. Buffer management aims to generate a rigorous construction plan that protects against uncertainties and reduces the potential impact of construction changes. The usage of buffer management in construction schedule is to complete activities without wasting time. Finally, the study illustrates the application of Critical Chain and buffers, especially in construction scheduling planning and control to achieve shorter project duration.

Keywords: Buffer Management, Theory of Constraints, Critical Chain, Scheduling and Control

1. INTRODUCTION

With the increasing complexity of construction projects, proper planning and control of project activities now represent key issues in the construction scheduling management. Generally, one objective of the construction schedule planning and control is to make successful on-time completion of each activity in project. Goldratt (1990) outlines how the Theory of Constraints (TOC) can be applied to projects to improve performance. Furthermore, the TOC approach focuses on successful on-time completion of the entire project. According to TOC, the main constraint in any project is the time taken for completion of the critical activities. Therefore emphasis is laid on completing activities in the critical path without wasting any time. In 1997, Goldratt introduce a new approach for project management, Critical Chain. The new concept is widely known and applied in practice. Critical chain in a project is defined as the longest sequence of activities from several different paths, connected by activities performed by common resources. The safety time in the Critical Chain is removed from individual activities and is utilized to create the project buffer. The project is to be guarded against delays by providing time buffers. Hence, cutting safety time from critical activities eliminates the major cause of time wastage, thereby removing the constraint. These buffers provide the necessary cushions to individual activities to enable them to accomplish the final goal of completing the critical chain in the least possible time. Horman et al (2003) explored the implementation of buffer management techniques for the planning and execution of the renovation of the Pentagon. Chua et al (2003) proposed an important methodology with work buffer management to integrate with constraints to RI availabilities. Also, Chua et al present methodology that augments the traditional critical chain method with RI availability constraints to analyze the causes of delay in buffer management [1]. Critical chain activities, which take less than the median time for completion, partially compensate for activities, which take longer than median time [6]. However, this does not mean that the project is to be left unprotected against any unforeseen delays in any individual activity [3]. However, the critical chain approach is not suitable especially on the estimation of buffers to absorb delays in construction projects. In order to enhance the usage and application of the Critical Chain approach in construction, the proposed buffers estimation is proposed in this study to enhance the practicability of application in construction scheduling. This study further discusses the main procedures and difficulties of Critical Chain approach in construction scheduling.

2. PROBLEM STATEMENTS

The CPM Network scheduling approaches have been extensively applied in construction to identify necessary activities and determine activity start and finish times. The basic CPM approach has the problem in the ability of dealing with non-precedence constraints although CPM approach is simple to use and solve sophisticated problems. However, many constraints exist in practice regard to construction project. Those constraints should be managed effectively in view of construction schedule planning and control. Most available methodologies to solve the non-precedence constraints include heuristic approach, optimal solutions, and simulation approaches [2]. These methodologies can find optimal or near-optimal solutions regard to the constrained resource and overcome the CPM problems. Another solution for solving the same problem is new methodology-Critical chain [11]. Critical chain is new methodology that applied the TOC to project management in order to complete projects faster. The following is main problems addresses by the Critical Chain:

1. Estimating Safety Time: When engineers make or calculate the duration estimations based their experience, most of engineers tend to add hidden safety duration into their estimations for any uncertainties. Although adding safety duration in activity duration estimate is not wrong, it is necessary to understand the implication of safety duration regard to actual performance [8].
2. Student' s Syndrome: Similar to when students are given assignments, they usually start assignments at the last minute even the length of time are enough. Therefore, the extra safety duration becomes a kind of waste because activity leads to late starts [8].
3. Parkinson' s law: People will simply adjust the level of effort to keep busy for the entire activity schedule. If an activity is estimated to take planned duration, it usually does not take less. Usually, people do not promote be early even they can finish the work ahead of schedule [8].
4. Multi-tasking: the effect of multitasking should be considered because that fragmentation of resource and equipment' s set up time would cause tasks to delay due to loss of concentration [11].

Although the above problems are commonly happening in construction projects, the traditional CPM approach can not solve these problems.

3. RESEARCH OBJECTIVES

The basic assumption of the CPM is that resources required by activities are unlimited. In most construction projects in practice, resources usually and always are limited in practice. Therefore, schedule without considering resource limitations may become an untrustworthy schedule because the start time of activities is usually affected by resource availability. According to the theory of constraints (TOC) [3], any project is possible to be restricted by one or a few constraints. Furthermore, the capacity of the constraint in activities effect the whole project durations. In order to finish the project ahead of planned schedule against limited resources, the application of buffers in the Critical Chain is utilized to solve the above mentioned problems. There are three types of buffers in Critical Chain include project buffer, feeding buffer, and resource buffer. To facilitate traditional CPM approach, those buffers will be utilized and integrated CPM approach to improve feasible arrangement in schedule through removing constraints in advance and decrease the impact for uncertainties. Furthermore, the problems and solutions using Critical Chain approach in the construction industry may be discussed in this paper.

4. METHODOLOGY

4.1 Theory of Constraints

Theory of Constraints (TOC) is a common-sense way to enhance system improvement [3]. Any system usually at least have a constraint that limits its output. The constraint likes that weakest part of the system. The system only becomes stronger until you improve the strength of the weakest part [3]. Goldratt propose a five-step process to achieve continual improvement and to get the most of overcome. Fig. 1 illustrates the sequence of the five steps [4].

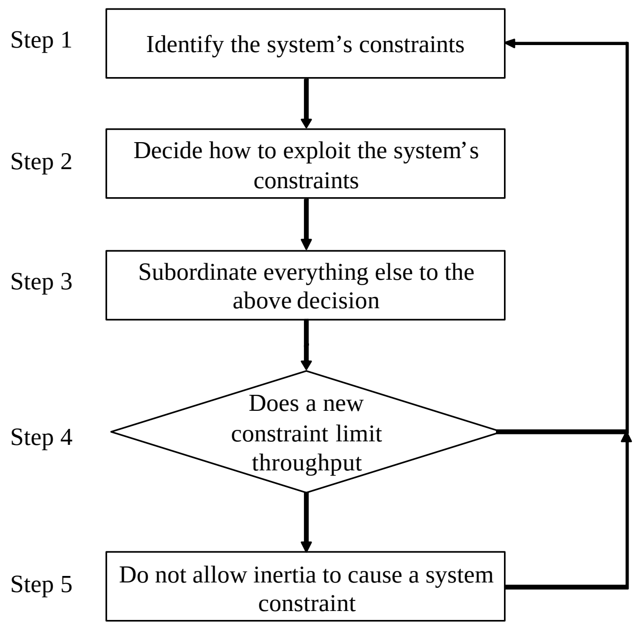

Fig. 1. The Five Steps Represent The TOC Approach [8]

4.2 *Critical Chain Project Management*

Goldratt propose a Critical Chain Project Management (CCPM) method to overcome some of the problems inherent in the traditional CPM method [5]. The critical chain method, apply the Theory of Constraints to offers an enhanced approach to manage the associated risk and uncertainty in the project to achieve performance in project schedule management.

4.3 *Buffer Management*

There are three kinds of uncertainties in project planning and scheduling namely, "activity time uncertainty", "path time uncertainty", and "resource uncertainties" [8]. In order to reduce those uncertainties, buffers are utilized and applied in the critical chain project management. In the critical chain, buffers are added durations and applied to a project schedule to protect what is important to the success of that project [8]. The buffers using in the critical chain include project buffer, feeding buffer, and resource buffer. The function of project buffer is to protect the promised due date from variation in the critical chain. The function of feeding buffers is to protect the critical chain to maintain its relay race performance by buffering the activities in non-critical chains and critical chains where they merge with activities in critical chain. With a properly feeding buffer durations inserted, the activity in critical chain that relies inputs from that non-critical chain has an improved chance of being able to start as soon as it predecessor activity in critical chain is complete. The function of resource buffer is an information signal to resources planned to work on the project critical chain that the project task is coming up for work. Resource buffers are unlike the other buffers, as they do not directly influence the scheduling of the project.

4.4 *Buffer Estimation Integrated PERT Approach*

With uncertainly be demonstrated to have an effect on the project, one of the well-known techniques for quantifying the impact of such uncertainty is Program Evaluation and Review Technique (PERT). The PERT approach was developed by the late 1950s [12]. To represent the uncertainty in duration estimates, the PERT technique recognizes the probabilistic, rather than deterministic, nature of the operations involved in high-risk activities. Accordingly, the PERT technique incorporates three durations for each activity into its methodology.
The three duration estimates are [12]:
Optimistic duration (a): estimate time of executing the activity under very favorable working conditions.
Pessimistic duration (b): estimate time of executing the activity under very unfavorable working conditions.
Most likely duration (c): estimate time of executing the activity that is closed to the actual duration. This estimates lies in between the above two extremes.

5. BUFFER MANAGEMENT IN CONSTRUCTION

In order to manage uncertainty in construction projects, buffer management is utilized to make assessment of the consumption and replenishment of buffers regard to activities and project. Buffer management may provide a clear view of the cumulative risk impact to the project performance. Compare with CPM approach, critical chain includes the consideration about resource constraint and focus on cause uncertainty management. The study focuses on the usage of buffer management in construction schedule without wasting time. Furthermore, the study finds out the problems to applying critical chain project management in construction.

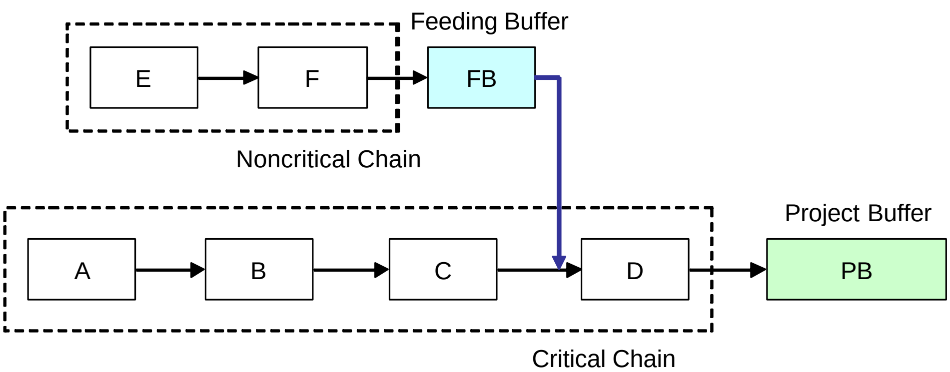

Fig. 2. The Application of Buffer in Critical Chain

The following is the brief illustration to the application of critical chain project management in construction. As same as the previous description, three estimated buffers are integrated with CPM approach. All procedures are shown in Fig. 2. The project buffer is placed at the end of the project after the last critical chain activity to protect schedule against overruns. The feeding buffer is placed at the intersection between noncritical chain and critical chain to protect the critical chain against overruns on these feeding chains. Resource buffer is placed at the critical chain to ensure that resources are available when needed to protect the critical chain schedule. Resource buffer helps insurance of resource availability, and does not add time to the critical chain.

In CCPM, Goldratt proposed that when making plan and schedule, the planner assumes that each activity may completes his work at the mean time without any impact of uncertainty. All the safety times in activities should be removed unnecessary wasting time. Furthermore, Goldratt suggests the size of buffer is 50-50 estimated duration [8]. However, the 50% estimation is too arbitrary and difficult to apply in construction real world. Also, the above approach is unsuitable in construction schedule plan. In order to improve the above problem, a modified approach is proposed to estate buffer more reliable. In construction, the duration estimation of each activity is usually estimated based on planner experience or calculated by average work production rate. However, the estimation usually is longer than the average time because planers always add safety time into the activity for any uncertainty. Usually, most of work estimates can not make sure 100% effort on the activity. If the activity estimation is not 100% effort or people work in the lax attitude, activity duration will be reduced and remove the safety time. In order to solve above problems, the two questions will be used and asked for each activity from participating engineers. First question is "How long could you perform this activity based on your previous experience?" Another question is "How quickly could you perform this activity if everything goes through well and you had all the inputs you needed at the start?" After you get the initial "protective" estimates from first question and obtain "reasonable" estimates according to question two. However, the engineers need to explain the reasons if the protective and reasonable estimations are same based on question one and two. After obtain the protective and reasonable estimations, the chief engineer may judge and determine the final estimating duration for each activity. Therefore, the safety time of each activity is protective estimation minus reasonable estimation. When buffer is increasing, it means that project may be finish ahead of schedule. On the contrary, it implies that the project will be possible to be delay if buffer is decreasing. The following is the main process applying buffers in construction projects.

Step1. Plan the construction schedule using CPM approach.

Step2. Identify and determine the protective estimation for each activity.

Step3. Identify and determine the reasonable estimation for each activity.

Step4. Remove the safety estimation for each activity based on Step 2 and Step 3.

Step5. Identify the critical chain as the longest chain of dependent events for the feasible schedule that was identified in Step 4.

Step6. Add the project buffer to the end of the critical chain.

Step7. Add the feeding buffers in a noncritical chain merging into critical chain.

Step8. Add the resource buffers to ensure the activity to resource availability.

Step 9 Return the Step 5 to check critical chain.

According to above procedures, the example is illustrated to explain the result. The total durations of schedule are 410 days based on the CPM approach and the total durations of revised schedule are 373.5 days using buffer management approach (see Fig. 3). Therefore, construction project planning is to be enhanced by the buffer management approach. Furthermore, those buffers can be utilized effectively in construction project for planning and controlling. In tradition project management, the critical path changes as activities are completed ahead of or fall behind schedule. With buffer management approach, buffers prevent the critical chain from changing during project execution. Briefly, the critical chain project management provides a rigorous plan and simplifies project control and utilizes buffers reduce the risk of a delay in construction.

6. CONCLUSIONS

The basic CPM/PERT approaches do not deal with the hidden constraints. Dr. Goldratt proposed the Theory of Constraints (TOC) and Critical Chain, which provide the concepts for achieving effective remove those constraints. The usage of buffer in TOC and Critical Chain emphasis is laid on completing activities without wasting time by using buffers. The buffers introduced in the critical chain scheduling methodology serve to protect project promises in a static manner. When activities take longer than the schedule anticipates, buffers are consumed. When they take less time, those buffers are replenished. Awareness of project buffer consumption relative to the completion of the critical chain provides an important forward-looking solution. Furthermore, removing safety time from individual activities can eliminate the major cause of time wastage and mitigate the impacts of constraints. According to the study, the application of buffers in project scheduling will improve the effectiveness specifically in the construction plan phase.

In the CCPM, the 50 % estimates are too arbitrary and do not apply in the real word regard to construction industry. In order to apply the Critical Chain in construction project, the new buffer estimation is integrated with CPM approach for buffer management in the paper. In the safety time for each activity, two estimations are used in this study. The proposed two estimations for buffers are suitable and applying for construction project management in practice. According to the result from face-face interviews, ratio to safety estimation in practice may be around between 0.1 and 0.2. More details for safety estimations are suggested for further study. Briefly, buffer management can make a steady plan to protect against uncertainties and reduces the potential impact of construction changes. This study illustrates the application of Critical Chain and buffer management can be well applied in construction projects to achieve shorter project duration without driving up costs.

7. SUGGESTIONS FOR FURTHER STUDY

An important area for further study is analyzing buffer consumption rates special for construction projects and recommending improved methods for buffer management in construction. The main reason is buffer estimations vary from activity to activity and project to project. It is recommended that buffer estimations versus work types are studied for numerous projects.

A second suggestion for further implementation study is with larger and more complex construction projects. It is necessary to study the application of buffer management and critical chain project management in construction larger and complex projects to track the progress of the results through completion and continue to provide lessons learned.

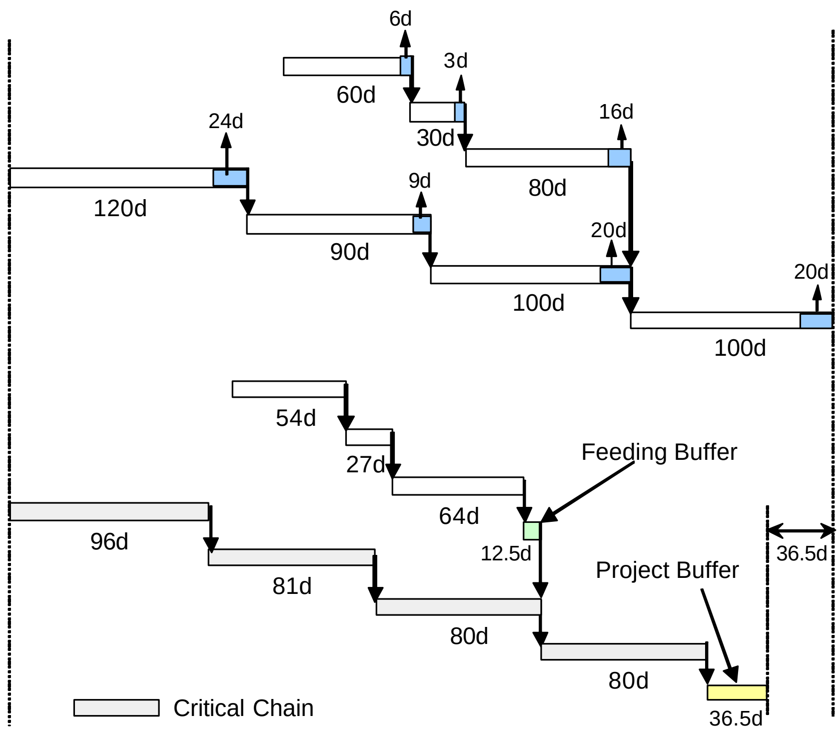

Fig. 3. The Application of Buffer Management Integrated with CPM Approach in Construction

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