In construction projects, one of the main problems in planning and control is determining the project schedule. Project managers and planners use an estimated time to attempt to ensure the completion time of either an activity or a project.

However, this traditional method can sometimes fail in optimising the project schedule, which can result in unnecessary time wastage. The Theory of Constraints (TOC) and Critical Chain were proposed by Dr. Goldratt in 1990, which provide the concepts for achieving effective activity duration control.

Critical Chain concepts are increasingly being accepted and applied in a variety of industries. This paper applies Critical Chain concepts in construction to manage buffers effectively in project scheduling, planning and control using Asta Powerproject. Buffer management aims to generate a construction plan that protects against uncertainties and reduces the potential impact of changes.

Asta Development provides a complete range of project management software solutions for managing all types and sizes of construction and engineering projects. Asta Powerproject comes with all the features to support Critical Chain project management (CCPM) without the need for add-ons or additional products.

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 contingency period in the Critical Chain is removed from individual activities and is utilised to create a project buffer. These buffers provide the necessary cushions to individual activities enabling them to accomplish the final goal of completing the Critical Chain in the least possible time.

Critical Chain can address the following problems:

**Estimating Contingency Period:** When planners calculate the duration estimations based on their experience, most tend to add a hidden contingency period into their estimates for any uncertainties. Although this is not necessarily wrong, it is important to understand the implication of safety duration with regard to actual performance.

**Student’s Syndrome:** Similar to when students are given assignments, they usually start assignments at the last moment. Therefore, the extra safety duration is wasted.

**Parkinson’s Law:** People will simply adjust the level of effort to keep busy for the entire activity schedule. Slowing down is a manifestation of Parkinson’s Law (Parkinson 1957); the work expands to fill the time available for its completion.

**Everyone adds their own Contingency Period:** If I ask the worker “how long will you need to dig the trench” he may think 4-days, but not wanting to put too much pressure on himself, says 6-days. His manager hearing this tells the contractor carrying out the work that it will take 10-days. The contractor when putting this into his schedule may increase the duration to 15-days. So a 4-day activity has expanded to 15-days for each party to protect their commitment. This cumulative contingency is hidden in the overall task duration.

Although the above problems commonly happen in construction projects, the traditional Critical Path approach may not solve these problems.
There are three kinds of uncertainties in project planning and scheduling namely; ‘activity time uncertainty’, ‘path time uncertainty’, and ‘resource uncertainties’. In order to reduce those uncertainties, buffers are utilised and applied in CCPM. In the Critical Chain, buffers are added durations that are applied to a project schedule to protect what is important to the success of that project, namely the finish date. The buffers used in the Critical Chain include ‘project buffer’, ‘feeding buffer’, and ‘resource buffer’.

The function of a ‘project buffer’ is to protect the promised finish date from variation in the Critical Chain. The function of ‘feeding buffers’ is to protect the Critical Chain and maintain its relay race performance by buffering the activities in both non-Critical Chains and Critical Chains where they merge with activities in a Critical Chain. (see image 1)

Critical Chain project management (CCPM) can be applied to construction projects by using Asta Powerproject. Let us assume we have created a critical path schedule with a required end date of the 4th November 2010. (see image 2).
In CCPM, Goldratt proposed that when making the plan, the planner assumes that each activity can complete in the meantime without any impact of uncertainty and the contingency periods in activities should be removed. Furthermore, Goldratt suggests the size of the safety amount is 50% of the estimated duration. However, the 50% estimation can be difficult to apply to construction projects. In construction, the duration of each activity is usually estimated based on the planner’s experience or calculated by an average work production rate. Nevertheless, the estimate is usually longer than the average time because planners generally add a contingency period into the activity for any uncertainty. In order to solve the above problems, two questions should be asked for each activity from the participating resource.

1. “How long could you perform this activity based on your previous experience?”
2. “How quickly could you perform this activity if everything goes well and you had all the inputs you needed at the start?”

After you get the initial ‘protective’ estimates from the first question and obtain ‘reasonable’ estimates according to question two, you can calculate the contingency period of each activity as being the protective estimation minus reasonable estimation.

Using our example project we will assume the part of each activity shown in blue is the contingency period (see image 3)
This contingency period is then removed from each activity, as shown in image 4, and replaced by a ‘project buffer’ and a ‘feeder buffer’.

The ‘project buffer’ is placed at the end of the project after the last activity in the longest path to protect against overruns (note: in this case the ‘project buffer’ is the cumulative duration of all the contingency periods that have been removed from the longest path).

The ‘feeding buffer’ is placed at the intersection between the non-Critical Chain and the Critical Chain to protect the Critical Chain against overruns on these feeding chains (again set at the accumulated duration of the safety removed from all non-Critical Chain tasks).

Resource buffers’ could be created by performing resource levelling within Asta Powerproject to ensure resource availability, but this is not done in this example.

In summary we should follow these steps:

1. Plan the construction schedule using the CPM approach.
2. Identify and determine the protective estimation for each activity.
3. Identify and determine the reasonable estimation for each activity.
4. Remove the safety estimation for each activity based on step 2 and step 3.
5. Identify the Critical Chain as the longest chain of dependent events for the feasible schedule that was identified in step 4.
6. Add the ‘project buffer’ to the end of the Critical Chain.
7. Add the ‘feeding buffers’ in a non-Critical Chain that merges into the Critical Chain.
8. Add the ‘resource buffers’ to ensure the activity to resource availability.
9. Return the step 5 to check Critical Chain.
Now that the contingency estimates have been moved from the activities into the buffer tasks, the planner actively manages the buffer consumption rather than concentrating on the on-time completion of individual activities.

Monitoring is, in some ways, the greatest advantage of the Critical Chain method. Because individual tasks will vary in duration, there is no point in trying to force every task to complete ‘on time’; estimates can never be perfect. Instead, we monitor the buffers that were created during the planning stage. If the rate of buffer consumption is low, the project is on target. If the rate of consumption is such that there is likely to be little or no buffer at the end of the project, then corrective actions or recovery plans must be developed to recover the loss. When the buffer consumption rate exceeds some critical value (roughly: the rate where all of the buffer may be expected to be consumed before the end of the project, resulting in late completion), then those alternative plans need to be implemented.

Its purpose is to provide a simple, easy to understand view of your project’s health against original promises and provide guidance on when, and when not to, develop and apply corrective actions to the project effort.

Using our example, let’s assume we are one week into the project and Dig Foundations should be 100% complete but is in fact only 30% complete. Note our current project buffer duration is 20 days. (see image 5)

If we recalculate the critical path, the delay on Dig Foundations impacts the duration of the ‘project buffer’ as it is absorbing the delay. (see image 6)

The buffer duration is now just under 15 days long. The spreadsheet shows that 26% of the buffer has been consumed. A positive number indicates the buffer is being consumed i.e. the plan is behind, and a negative number indicates the plan is ahead. A ‘buffer rag column’ can show visually if the buffer consumption is too high. (see image 7)
Using Asta PowerProject for Critical Chain and Buffer Management

As the plan progresses, we can plot the buffer consumption in Asta Powerproject. In the example shown in image 8, the consumption of the buffer is monitored and as long as the consumption is within the green area we can assume the project is progressing well. Movement into the red and amber areas would be cause for concern.

With a buffer management approach using Asta Powerproject, buffers prevent the Critical Chain from changing during project execution. The CCPM provides a rigorous plan, simplifies project control and utilises buffers to reduce the risk of a delay in construction, as well as bringing in projects ahead of schedule without increasing costs.

Another practical use for buffers deals with the common practice in a construction project of having an ‘internal’ or ‘target’ schedule, which is less than the ‘contract’ schedule. Instinctively this is a practice to mitigate against Parkinson’s Law. So, for a contract duration of 95-weeks the contractor may be operating on a target plan of 85-weeks.

The motivation for this is to reduce the likelihood of over-runs and limit the exposure to fines (Liquidated Damages) for exceeding the project end date. Progress on the plan is reported to the client’s representative and design team against the original 95-week plan. The contractor has great reluctance to declare the 85-week plan as he is fearful that someone will remove the 10-weeks contingency.

This does cause some serious problems, particularly in the early stages of a project (before the contingency/buffer starts to be used up). The client needs a reasonably accurate cash-flow prediction so that he can arrange funding for the project. This is initially provided from the 95-week plan, but the contractor is likely to be 10% ahead of the payment plan and so can cause the client to experience funding difficulties. In addition, the procurement steps before each major Work Package are planned to arrive at a meaningful schedule of when the design information is required. Presenting design required dates from the 85-week plan can be very difficult to justify if only the 95-week plan is made public. Two plans have to be updated for progress; the ‘target’ and the ‘contract.’ This makes unnecessary work for the project manager.

The best technique to unify the ‘target’ and ‘contract’ plans is to explicitly declare the contingency as a buffer and monitor its consumption. The barriers to such a declaration are mainly political within an organisation and can be affected by the type of contract e.g. the NEC form of contract recognised a project buffer as terminal contingency, which is owned by the contractor and not the project (unlike the float).
Asta Powerproject Overview

Asta Powerproject is a project management software tool, which is widely used both in the UK and internationally to manage construction and engineering projects of all types and sizes.

Launched in 1988, Asta Powerproject is well-proven as an easy-to-use, powerful professional project management system. It is used to manage all aspects of construction and engineering projects such as producing tender plans, delivering against the contract programme, reporting progress to clients and management, controlling costs and resources, mitigating against the risk of delay and disruption, and producing robust schedules that reflect exactly what happens on site.

Asta Powerproject is used by both small and large organisations, including some of the world’s largest construction and engineering companies. It is available as standalone software for individual users, networked software and as an enterprise system for managing complex projects where three or more planners need to work on the same project at the same time.

High profile projects where Asta Powerproject has been used include The London Eye; the Eden Project in the UK, the Space Shuttle, Schipol Airport in the Netherlands, Hong Kong Airport, Petronas Towers in Malaysia, Jumeirah Park, Dubai, Renewable Energy Projects in France, the Commonwealth Games Village in India and the Reichstag in Berlin. It is also used on everyday projects such as house building programmes, refurbishment, highways maintenance and commercial developments.

For further information on this topic or any other topics using Asta Power Project, contact Asta Development on:

T: +44 (0) 1844 261700
E: enquiries@astadev.com