



Critical chain: the theory of constraints applied to project management

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Abstract

In his recently published third novel, *Critical Chain*, Eli Goldratt applied his Theory of Constraints to project management. This paper explores the relationship between the ideas developed in the novel and the CPM/PERT approach. © 2000 Elsevier Science Ltd and IPMA. All rights reserved.

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1. Introduction

In the early 1980s, a novel was published which has subsequently been read by many hundreds of thousands of executives, production planners and shop floor workers. *The Goal* [1] sets out Eli Goldratt's ideas on how production should be planned. The methodology was made available in the production planning system OPT (Optimised Production Technology) which was marketed by Creative Output Inc [2]. These ideas were later broadened to encompass other areas such as marketing and distribution in a further novel, *It's Not Luck* [3], and the theory widened to become the Theory of Constraints. Technical details are found in two further books [4,5].

In his third novel, *Critical Chain* [6], Eli Goldratt demonstrates the application of his Theory of Constraints to Project Management. The novel is set mostly in an American MBA class, and the ideas are developed in discussions between the lecturer and the students. The lecturer is fighting for tenure with the

University President, who expects a downturn in the Executive MBA registrations.

The lecturer is teaching project management as a result of discussions between himself and a senior colleague. He wants to teach a course that will create synergy with his research. He says he doesn't want to chase fads, or go into a field that is overcrowded with research. He tells his colleague that he wants a field in real need, a field in which no real progress has occurred for quite some time. His colleague responds:

project management fits your description like a glove. If you are looking for a field in need, project management is a prime candidate. And in the last forty years or so, at least in my opinion, nothing new has been suggested.

Three of the students have been placed in a project team in their company, with a brief to reduce the development time for new electronic products. They come together in the MBA class and, together, with the other students, they discover a new approach to project management, the Theory of Constraints. This results in such a successful class, by achieving excellent practical results and thus gaining the backing of the students' employers, that the lecturer's tenure is saved, and for all concerned there is a happy ending.

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Detailed reviews of *Critical Chain* have been published [7,8]. Newbold has also presented these ideas [9]. ProChain Solutions Inc market an add-on to Microsoft Project and a package, ProChain Plus, that deals with multi-project scheduling (which is apparently the subject of Goldratt's next book). Their website is <http://www.ProChain.com>. In an evaluation of the ProChain software, Steve Cotterell concludes that it is "the TOC and the psychology behind it that is the driving force, with ProChain being a useful tool that supports and enables it" [10].

2. The theory of constraints

Readers not familiar with the Theory of Constraints may rest assured that they, like the characters in the novel, will be given a suitable introduction. For the hero of the novel this is achieved by means of a seminar, which he reluctantly attends, given by an enlightened colleague who has spent some time in a company wedded to Goldratt's ideas. In addition, a web site is available: <http://www.goldratt.com>. A brief description, of course, is appropriate here. The Theory of Constraints is based on five steps.

1. Identify the system's constraint(s)
2. Decide how to exploit the system's constraint(s)
3. Subordinate everything else to the above decision
4. Elevate the system's constraint(s)
5. If, in the previous steps, a constraint has been broken, go back to step 1, and do not allow inertia to cause a system's constraint.

The system's constraint is that part of the system that constrains the objective of the system. For money making organisations, Goldratt defines the objective as being to make more money, now and in the future. In production planning terms the system's constraint is the bottleneck. In Step 1 this needs to be identified. If it is a machine, for instance, then the maximum possible utilisation needs to be achieved. This may mean running the machine during the lunch hour, with operators staggering their break, or reducing the number of changeovers. It will mean ensuring that there is always work for the machine to do. Thus the system's constraint is exploited (Step 2). If this is the constraint, then there is no point running other machines at a higher production rate: so every other planning decision needs to be subordinated to the schedule required to keep the bottleneck machine running (Step 3). To improve the objective the system's constraint may need to be 'elevated'. In the case of the bottleneck machine, for instance, it might be run during an additional shift, thus increasing its output. The constraint, the capacity of the machine, has been increased, or 'elevated' (Step 4). The difference

between Step 2 and Step 4 relates to the amount of investment required, whether in terms of time, effort, money, or willingness. The difference is sometimes pithily expressed as "whatever we can do tomorrow is Step 2". The application of Step 4 may have changed the system's constraint. With its increased capacity, the original bottleneck may no longer be constraining the system, so the new bottleneck needs to be identified, and the process repeated (Step 5). Thus, this is a process of continual improvement. Though this example comes from the production environment, TOC is applicable to every system. *Critical Chain* seeks to explain how this approach can be applied to project management.

3. Why is a new approach needed?

Why should there be need for other methods for Project Management to replace, or perhaps enhance, CPM/PERT? Self-evidently, CPM/PERT frequently does not work. Almost daily, examples of project overruns can be discovered in the media. Goldratt quotes some of the better known examples: the Channel Tunnel and North Sea oil rigs. Though why solely European examples of failure should be quoted in the discussions of an American MBA class is not clear. When it is explained that overruns are not inevitable, the example of projects that were completed on time is from the US: the development of the U-2 spy plane.

The reason for the development of *Critical Chain* is the existence of chronic problems that existing methods, approaches and even expensive software have not been able to remove. Problems like late completion, over spending, the need to cut specifications and other undesirable effects with which every project manager is familiar. The inability to deal with such problems calls for a thorough and rigorous analysis and the use of the TOC approach, which is to find the core problem and then invent a breakthrough solution. This requires the use of the three TOC improvement questions: what to change?, to what to change? and how to cause the change?

Goldratt argues that there are two conceptual breakthrough ideas. First, what he calls the throughput mind-set. He encourages managers to 'think global and not local'. This requires the use of cause and effect to understand the impact of an action or decision in one part of the project on the other parts as well as the ability to achieve the objective of the project—on time completion within budget and specifications. Secondly, the way the basic behaviour of the project management environment is handled. The environment is characterised by dependent events with statistical fluctuations. In such an environment the provision of

safety time and its use is of crucial importance, and is highlighted later in this article.

Goldratt argues that the main reason for project overrun is because of the misuse of the safety time created within the estimated times for each activity. He believes that a consequence of the three time estimates used in PERT and their weighted mean being used for scheduling by CPM, will be a tendency to overestimate the times to give a reasonable degree of certainty of completion. “The uncertainty existing in every project is the underlying main cause for most problems. Now we see that people are not blind to it and they do add a lot of safety in their planning” is how Goldratt puts it. As uncertainty is a fact of life in any significant project, it is the management of that uncertainty that is the key issue.

If safety time is built into each estimate, this would imply that, when all activities are linked together, there should be a high probability of completing on time. So why do we see a high proportion of overruns? The answer to this, according to Goldratt, again lies in management’s understanding of the psychology of the workforce. Because the employees know that safety time is built into the estimates they think that they do not need to worry about starting on time. So starts are delayed. In the book this is called the ‘student syndrome’—leaving everything to the last minute. If only faculty were immune to this trait! If starts are made on time, there is a tendency not to go at full steam, because of the feeling that there is time in hand. One cause of this is likely to be multi-tasking, where there is always pressure to be doing something else.

The next effect he identifies is that preparation for the next stage is not made, because it is not clear when the previous activity will finish. As a result, activities are not ready to start when the previous activity actually does finish. A final argument is that completed activities may not be released early, because of the expectation that, in the future, pressure will be applied to finish early. The next time a project is planned, superiors may reduce the time estimates supplied, on the grounds that a better-than-forecast activity duration was achieved last time. A magazine recently ran a ‘Dilbert quotes’ contest. They were looking for people to submit quotes from their real life Dilbert-type managers. One of the submissions, which were circulated extensively on email, was:

Doing it right is no excuse for not meeting the schedule. No one will believe you solved this problem in one day! We’ve been working on it for months. Now, go act busy for a few weeks and I’ll let you know when it’s time to tell them.

(R&D supervisor, Minnesota Mining and Manufacturing/3M Corp.).

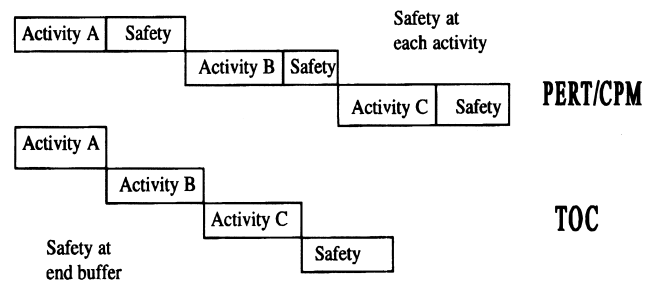


Fig. 1. Comparison between PERT/CPM and TOC with regard to safety time.

4. What approach does the Theory of Constraints adopt?

PERT deals with uncertainty in the same way for all activities, whether or not they are on the critical path. The approach of the Theory of Constraints is to relocate the safety times in strategic positions. Time estimates may be reduced (if it is known they are inflated), but safety buffers of time at the end of the project, called the ‘project’ buffer (see Fig. 1), are added. This will have the effect of reducing the length of the critical path. It should be noted that the decision to cut the overall safety time is subject to the level of confidence that concerned parties have in this process. The Goldratt Institute recommend that the first emphasis should be on finishing on time, before looking for a reduction in overall time: in the TOC language, they go for ‘exploit’ before ‘elevate’.

The activities on the critical path need to be able to start when the previous activity(ies) on the path are completed. They should not be required to wait for any sub-critical activities. So ‘feeding’ buffers are added at the end of the non-critical sub-paths (see Fig. 2). Resource buffers may be needed to deal with critical resources, in order to protect the critical chain for resource availability. It is argued that the drastic cut in activity times will have the benefit of removing procrastination, the ‘student syndrome’, because those involved are concerned about whether or not they can finish the activity on time.

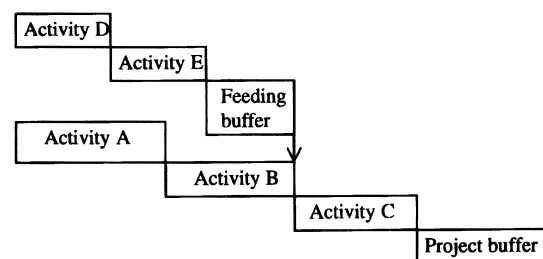


Fig. 2. Arrangements of buffers in the TOC approach to project management.

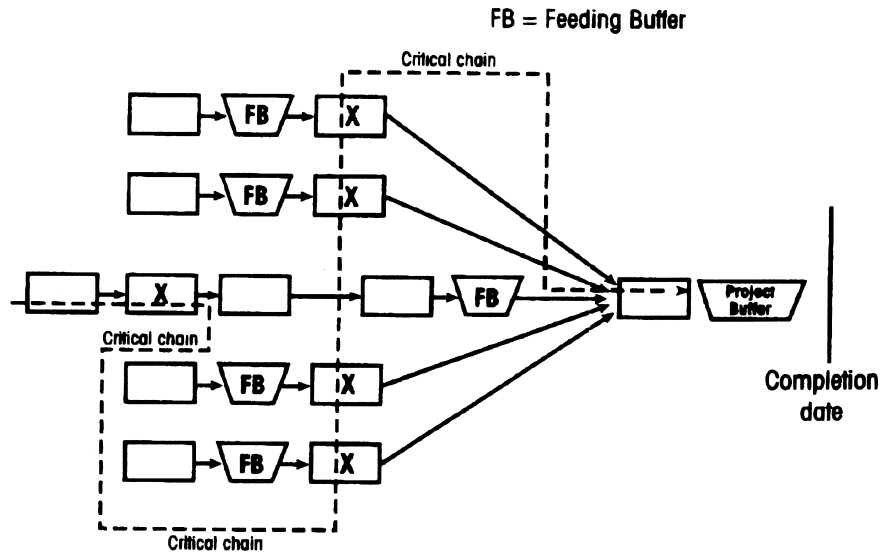


Fig. 3. An example of a critical chain.

5. Controlling the project

As is the case with a straightforward application of PERT/CPM, it is vitally important to control the ongoing project in order to keep it on track. How does TOC approach this concern? The first requirement is to ensure that preparations are made to start activities when they are passed over. One aspect of this is the creation of a resource buffer for activities on the critical path. The time of completion of ongoing activities is estimated, and the appropriate resources required for the subsequent activities are told to be available. The aim is that people know that when the time comes they must drop everything and work on the critical path. They are encouraged to start immediately, work only on the critical task and finish promptly. It is clear that it is necessary to prevent multi-tasking interfering with the start of a critical activity. Multi-tasking is a crucially important aspect of project management that needs to be controlled. Thus, *Critical Chain* spends some time dealing with it and it has given rise to endless discussions in the email discussion groups devoted to this topic.

6. Creating the critical chain

It is in the context of resource allocation that the term 'critical chain' is introduced. It is frequently the case that limited resources are required to work on several activities of the project. How is it determined which activity should be worked on at any specific time? The critical chain is defined as the longest chain of dependent steps: in other words, the constraint. To determine this, it is necessary to take into account any

dependencies that might exist between activities because they require the same resource. If that is the case, they must be carried out sequentially, rather than in parallel. This can be illustrated in a diagram taken, with permission, from the *Critical Chain* (Fig. 3).

7. Conclusions

In *Critical Chain*, other aspects of project management are dealt with, such as the issue of subcontracting work on price and not on lead time or reliability. In contrast to PERT/CPM, which may be characterised as dealing solely with certain technical aspects of project management, the application of the Theory of Constraints focuses very much on how senior management deal with human behaviour, both in terms of constructing the project network, and in managing it afterwards. As far as the technical aspects are concerned, the key messages are to avoid milestones, to focus on the critical areas, by identifying the critical chain, and to insert buffers at the appropriate points in the project network.

Milestones have become so ingrained in project management culture, that it is startling to discover someone recommending that they should be avoided because they can lead to delays in project completion. For many this will be counter-intuitive. Whether the point is accepted will depend on your understanding of the psychology of your workforce, as argued earlier in the section on why a new approach is needed.

The concern about focusing on the critical areas is well established in project management, as exemplified by the critical path, so the extension to the critical

chain, incorporating activities that use scarce resources is not likely to be dismissed out of hand.

The concept of buffers, whether project, feeding or resource, is one that can easily be added to existing approaches, though there may be unwillingness to cut activity times, as is implied by the use of buffers.

At a conference, organised by the Goldratt Institute in May 1998, Philip Baylis of Balfour Beatty Civil Engineering Ltd., gave a presentation on the use of these ideas in various construction projects. The Theory of Constraints had been successfully used. In the first project in which the concepts were applied, handover took place two weeks early, with 99.5% of all work completed. He concluded that it is an essential tool to assist in the delivery of a successful project.

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