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Project management applications of the theory of constraints beyond critical chain scheduling

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Abstract

The application of the Theory of Constraints (TOC) is an approach that can be used to develop a variety of management techniques. As a result of the multi-disciplinary nature of project management a variety of different applications within project management are possible. The application of the TOC approach to project scheduling led to the development of the "critical chain" technique that has been the subject of discussions in literature. This paper explains why TOC was initially applied only to project scheduling. A second application of TOC is to manage resources shared by a number of concurrent projects. The basic principles of this second application are discussed in this paper. In addition to the above-mentioned two applications the TOC approach can also be applied to other areas of project management such as project cost management and project risk management. © 2001 Elsevier Science Ltd and IPMA. All rights reserved.

Keywords: Theory of constraints; Critical chain; Project risk management; Project schedule; Project network; Resource scheduling; Project cost management; Multi project; Resource allocation; Human behaviour

1. Introduction

The Theory of Constraints (TOC) is an approach that is used to develop specific management techniques. It was first popularised by the novel, *The Goal* [1], that applied the principles to operations management. Since 1997 it has found application in two areas within project management. The first application is scheduling of a single project to reduce project duration and simplify project control. This is the main theme of the novel *Critical Chain* [2]. Only towards the end of this novel (Chapter 24) there is some indication of a further application to allocate resources that are shared by concurrent projects.

The assumptions and principles underlying the application to the scheduling of a single project have been investigated in an earlier paper [3] that, like most literature to date, covers only the application to individual projects. A few authors [4,5], however, do mention the application to multiple concurrent projects that is already being used in practice. The basic principles of this application are discussed in this paper. This paper further illustrates that the TOC approach can also be applied to areas such as project risk management and project cost management.

2. Scheduling a single project — critical chain scheduling

Traditionally time estimates for individual activities contain some provision for contingencies. Critical chain scheduling aggregates these provisions into a *project buffer*. As a result of aggregation the total contingency reserve and thus project duration can be reduced [3]. Because contingency reserves are removed from individual activities and aggregated in a project buffer, commitments regarding the completion date are only made at project level. All other people working on the project only make realistic estimates, communicate expectations on activity durations and attempt to meet the realistic estimates. This implies that all due dates on individual activities and sub-projects are eliminated [3]. Team members know that there is some allowance for contingencies (a buffer) but if they need to use some of it, they have to make this need visible and motivate it. This requires a mindset that is quite different from the one that normally prevails where all people working on activities are required to commit themselves to due dates [3].

Advocates of TOC often claim that in traditional project management provisions for contingencies are

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too large because people might tend to commit themselves only on time estimates that they could meet with a high level of certainty. Also, managers or co-ordinators at each level within an organisational hierarchy could build in their own reserves on top of the reserves built in by the people reporting to them. It is furthermore believed that there is a tendency to waste time as a result of reserves that are liberal. Should these assumptions be correct (the author supports this view), it would strengthen the case for critical chain scheduling. However, should the assumptions be incorrect the TOC way of scheduling will still reduce project duration because of the effect of aggregation [3].

In traditional project scheduling the critical path does not take resource availability into account and resource allocation is done as an additional step. The critical chain, however, takes resource availability into account to the extent that activities done by the same resource are scheduled in series. To prevent non-critical activities from delaying critical ones, *feeding buffers* are placed where non-critical paths feed into the critical chain. A feeding buffer contains most or all of the contingency reserve relating to the relevant non-critical path. Proper management of the feeding buffers prevents the critical chain from changing during project execution and leads to a rigorous project plan [3].

3. Reasons for the emphasis on scheduling

In applying the TOC concepts to project management Goldratt and other advocates of the TOC approach limited themselves initially to project time management and did not venture into other aspects of project management. Here is why: the TOC approach prescribes that the constraint of a system has to be identified and attention focussed only on the constraint until it is not a constraint any more. Project duration is considered the major constraint of projects in general. Three reasons for identifying project duration as the constraint are discussed below.

3.1. Positive cash flow obtained faster

Project costs often escalate as a result of extended duration. As the schedule of a project with a fixed scope increases, costs usually increase [4]. Furthermore, revenues are often reduced as a result of delays. Project duration and project budget are sometimes traded off with the assumption that reduced project duration would be possible only with an *increase* in project costs. The most common time–cost trade-off technique with this assumption is one that was developed in 1957 by the DuPont Company and Remington Rand Univac. This is often referred to as the Critical Path Method or CPM. The reason for this apparent discrepancy is that authors on techniques such as CPM often consider the project itself as an end on its own, while in reality the project often only exists to create another system or product. The objectives of many projects are to establish products, services or other outcomes that exist well beyond project closure. The *product* life cycle as opposed to the *project* life cycle has to be considered. The project life cycle only forms the first phase of the product life cycle. Although the product life cycle is described in systems engineering literature and in certain literature on project management such as BS6079 [6], it is neglected in much of the other literature on project management that consider hand-over, project closure and the lessons learned as the ultimate goal. Each system has a goal. If the goal of the project is to deliver a specific product or system, the resulting product or system should have some beneficial goal. In business the goal normally is to generate money through sales. The objective of the project should be to maximise the revenue of the resulting system or product. Total product life-cycle costs and total product life-cycle benefits (rather than the project budget) should be the main considerations. To plan and execute a project normally results in an initial negative cash flow. The objective of the rest of the product life cycle should be to obtain some benefit (a positive cash flow in the case of projects done for business reasons). If project risks are taken into account, the positive cash flow should generally far exceed the negative cash flow. Therefore, if a project were to be delayed, the overall effect on cash flow (or other positive outcome) could be expected to be impaired. If the *product* life cycle (as opposed to *project* life cycle) is considered, it often makes sense to reduce project duration in order to improve the internal rate of return even if it requires greater expenditure during project planning and execution. The optimisation of total product life-cycle benefit is the *first* motivation for the assumption that project duration is a very important constraint.

3.2. Contingency cost of delays

A *second* motivation for considering duration as an important constraint is that the contingency cost of project delays could be very high. For example, market share could be lost if a project is delayed. This is mentioned in the context of new product development in *Critical Chain* [2].

3.3. Preventing changes to stakeholder needs

A *third* reason is that it is believed that extended project duration not only leads to escalation of overhead costs, but also leads to scope changes because stakeholder needs could be expected to change over time. While scope changes are often not allowed, there are cases where scope changes during the project life cycle are permitted. When a project is completed early there is less time for the stakeholders' needs to change and