

# Extending project time–cost analysis by removing precedence relationships and task streaming

Matthew J. Liberatore<sup>a,\*</sup>, Bruce Pollack-Johnson<sup>b</sup>

<sup>a</sup> *Department of Decision and Information Technologies, Villanova University, Villanova, PA 19085, USA*

<sup>b</sup> *Department of Mathematical Sciences, Villanova University, Villanova, PA 19085, USA*

Received 26 April 2005; received in revised form 12 July 2005; accepted 28 April 2006

## Abstract

Faster completion of projects continues to be an important problem in project management. The traditional approach to reduce completion time has been to shorten the time required for performing a particular activity, often called crashing. In this paper, we propose the addition of two related approaches to expedite a project: increasing the parallel processing of tasks by completely removing precedence relationships, or streaming tasks by fractionally removing precedence relationships. We present a quadratic mixed integer programming approach for reducing project completion time that considers crashing as well as the removal and modification of precedence relationships. Our model extends the linear formulation of the deadline time–cost problem. Two examples are presented to illustrate the suggested approach. Project managers who wish to expedite their projects are advised to consider the benefits and costs of doing more tasks concurrently, or overlapping them, in addition to compressing task times.

© 2006 Elsevier Ltd and IPMA. All rights reserved.

*Keywords:* Managing projects; Time–cost analysis; Critical path method; Reducing project completion time; Concurrent processing; Task streaming

## 1. Introduction

Faster completion of projects has always been an important problem in virtually all project environments. Completing a project earlier may generate additional revenue, although added costs may also be incurred to speed completion of certain tasks. For example, in construction often there are financial incentives for expediting the completion of a project. In pharmaceutical product development, shorter development time can lead to extended patent-protected product sales. In addition, earlier project completion can create time savings in which firms can generate sales, enter markets early, grow those markets quickly, and invest in future R&D initiatives. A recent study estimated that direct out-of-pocket expenditures for Phase I through the final phase of new drug applications are approximately \$30,000 per day [11].

A number of approaches have been proposed to expedite project completion. Consider the following example concerning a typical construction project. The erection of formwork always precedes the placing of concrete. This precedence relationship cannot be removed, at any expense. On the other hand, we might initially assume that landscaping work could not begin until after the installation of the gutters and downspouts was completed. It is certainly conceivable to allow the landscaping and the work on the downspouts and gutters to happen concurrently (or even to start the landscaping first). It is quite possible that doing the tasks in parallel in this way could lengthen the time needed for the landscaping a bit (for instance, some extra raking and cleanup near the downspouts). Yet removing the precedence relationship could reduce the total project completion time if both of these tasks were on the original critical path, even though it involves lengthening the duration of one of the tasks. Alternatively, we might decide to overlap both activities, initiating landscaping work once a portion of the gutter and

\* Corresponding author. Tel.: +1 610 519 4390; fax: +1 610 519 5015.  
*E-mail address:* [matthew.liberatore@villanova.edu](mailto:matthew.liberatore@villanova.edu) (M.J. Liberatore).

downspout work has been completed. Again, this may lengthen the landscaping work but perhaps not to the same extent as in the previous example and perhaps not with the same time savings. The purpose of this paper is to present an integrated modeling approach that considers all three methods for finding the most cost-effective plan for expediting the completion of a project.

## 2. Literature review

There are several streams of research that investigate approaches for reducing project completion time. Vandenbosch and Cliff [22] discuss approaches for altering a project network to reduce completion time by moving from serial to parallel processing of activities, which de facto involves removing or modifying precedence relationships. The traditional stage/gate process consists of a number of sequential steps and requires that formal evaluations are made at critical points in the process to decide if the project is ready to proceed to the next stage or needs to be reworked. The compression strategy calls for the project team to compress or shorten certain critical stages in the stage/gate process. Concurrent or flexible processing requires that several stages of the development process are conducted in parallel. Like the concurrent model, flash development encourages concurrent processing of activities. However, it uses clustered overlapping stages which have coordinated completion times and limited intermediate checkpoints. However, this line of research does not explicitly model the time–cost tradeoffs inherent in altering all or portions of a project network from sequential to concurrent or overlapping stages.

A number of authors have conducted research that focuses on reducing project completion time using concurrent processing (e.g., [3,15,19,20]). Krishnan et al. [15] propose a model-based approach to determine how to best overlap a pair of sequential activities. Their approach incorporates information exchange between the upstream and downstream activities at the start of each iteration of the downstream activity. The model seeks to determine how many iterations of the downstream activity are needed to reduce completion time of the coupled activities.

Another line of research considers how to best subdivide work to reduce completion time. Meixell et al. [17] draw on coordination theory to develop a model that determines how best to subdivide an activity into a series of activities. Their approach considers both the increasing costs of coordination that result when an activity is subdivided, and the benefits of division of labor due to an increase in specialization. Trietsch and Baker [21] present models that determine how to best “stream” lots (i.e., break into sublots) to reduce the total time for jobs that are sequentially processed on multiple machines in a shop. Although the lot streaming concept has not yet been applied in project management, it is possible to “stream” an activity so that after completion of a portion of an upstream activity the downstream activity can start.

In the project management literature the analysis of the effects of reducing the time required for performing a particular activity is well-known and was in fact the motivation for the critical path method [14], originally known as the time–cost tradeoff problem. Here the amount of time required to complete an activity can vary according to how much the planner is willing to pay for it, since completing it sooner will usually require more or higher quality resources, at a higher cost. This problem is expressed in one of two ways: minimize the time to project completion (sometimes called the *makespan*) subject to a budget constraint (the *budget problem*), or minimize the total project cost subject to a bound on the makespan (the *deadline problem*).

The literature contains linear, nonlinear, and discrete formulations of the time–cost problem. The linear formulation assumes that each activity’s time can range over a closed interval, and that the cost of completing the activity is linear and decreasing over the interval. This problem can be formulated as a linear programming problem, and there are exact specialized solution algorithms that take advantage of the project network’s structure [10,13]. The nonlinear problem in its simplest form has been modeled using a piecewise linear representation of the time/cost tradeoff for each activity [18], to represent the common situation in which it becomes proportionately more expensive to reduce duration by each successive time unit (since each successive unit represents a larger percentage reduction). The discrete version requires specifying a set of discrete processing times and associated costs for each project activity, which is a different way to model nonlinearity. The budget version of the discrete problem recently has been shown to be strongly NP-hard [9]. A complete review of the time–cost literature can be found in Brucker et al. [2]. Recent research includes development of lower and upper bounds based on network decomposition [1] and modeling budget uncertainty [23].

A technique called the precedence diagramming method [6] is one way to reflect different types of precedence relations between activities in a project. The traditional precedence relation is a so-called “finish-to-start” relationship: the later activity cannot start until the preceding activity has completed. Precedence diagramming allows for “start-to-start” precedence with lag times, for example, so that it can be specified that one activity can start no less than a certain number of time units after the preceding one has started, whether or not the earlier one is completed yet. In a similar manner, “finish-to-finish” and even “start-to-finish” relations with lag and lead times can also be specified. These generalized precedence relationships, along with activity constraints (“start as early as possible” or “start as late as possible” within available slack), and external time constraints (“start no earlier than” or “finish no later than”) can be incorporated into the time–cost problem formulation [5]. These generalized precedence relationships and activity and external time constraints are fixed and not subject to decision-making.

متن کامل مقاله

دریافت فوری ←

**ISI**Articles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات