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A practical approach to project scheduling: considering the potential quality loss cost in the time–cost tradeoff problem

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Abstract

Crashing project activities is a typical way to shorten their completion times to meet project due dates, and previous research on quality in time–cost tradeoff problems focused on maximizing the individual activity quality of projects. However, implementing project scheduling that takes into account the potential quality loss cost (PQLC) in time–cost tradeoff problems is a practical approach, since individual activity quality is defined by conformance to project contractor requirements. We propose a mixed integer linear programming model that considers the PQLC for excessive crashing activities. This model will help project planners develop practical project schedules.

Keywords: Project scheduling; Quality; Potential quality loss cost; Time–cost tradeoff; Critical path method

1. Introduction

Successful projects should be completed before project due dates and within budget; however, these limits are sometimes surpassed. There may therefore be significant variance between the assumptions made regarding a project and actual outcomes. Sudden unexpected changes in construction technology, techniques, materials, or human resources can create budgetary and scheduling pressures that in turn may increase the possibility of failure (Zeng et al., 2007). A survey exploring the completion of construction projects in Saudi Arabia showed that 76% of project contractors experienced delays of 10–30% of the projected duration (Assaf and Al-Hejji, 2006).

A typical technique used to mitigate scheduling pressure is to crash project activities. Crashing activities involves allocating more resources (such as materials, labor, and equipment) than planned in order to complete a project more quickly (Kessler and Chakrabarti, 1999).

In time–cost tradeoff problems, projects are not always completed as scheduled without reworking or modification. A project is a one-time task constrained by time, cost, and quality, and its success depends on how well these constraints are balanced (Atkinson, 1999). If any one of the constraints is overemphasized, burdens may fall on the other two. Hence, crashing project activities should be considered a significant factor in the time–cost tradeoff problem.

Some previous studies have treated quality as an important factor in tradeoff problems, claiming that overall project quality attained by project activities should be maximized within a given deadline and budget. These studies have also promoted using a continuous scale from zero to one to specify the quality of each activity (Babu and Suresh, 1996; Tareghian and Taheri, 2006, 2007).

However, a study evaluating the application of the time–cost–quality tradeoff model to linear programming for a cement factory construction project in Thailand revealed two facts: overall project quality cannot be sacrificed by crashing, and individual activity quality is primarily determined by subjective judgements,

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with the exception of a few measurable activities (Khang and Myint, 1999). In real situations, even if overall project quality meets project quality targets, if any single project activities do not meet the project contractor's requirements, rework or modification may be necessary and are associated with time delay and cost overrun. The possibility of rework or modifications must be considered when crashing project activities to develop practical and cost effective project schedules.

This paper proposes a mixed integer linear programming model and procedure that accounts for potential quality loss cost (PQLC) associated with rework or modifications that may occur due to excessive crashing activities. The rest of the paper is organized as follows. Section 2 summarizes previous research related to time–cost tradeoff problems considering project quality. Section 3 describes the mixed integer linear programming model used to compute direct project costs, which was previously considered to be equal to the nonconformance activity rate of the project activities. Section 4 validates this model with an example and discusses the PQLC estimation method of the example project. Section 5 provides the conclusions of the study.

2. Literature review

The critical path method (CPM) that is used for all types of projects, such as construction, engineering, facility maintenance, software development, and research and development is a mathematical algorithm used to schedule a set of activities in a project. This method is fundamentally related to the tradeoff between completion time and the costs of the project (Kelley and Walker, 1959), and is suitable for application to deterministic conditions rather than probabilistic conditions. The CPM can be used to determine the time–cost tradeoff for activities that meet given completion times at minimum cost, and is useful when there are similar experiences from previous projects (Hillier and Lieberman, 1995).

Time–cost tradeoff problems from the late 1950s mostly concentrated on shortening overall project duration by crashing the time required to complete individual activities. Researches in this area include linear programming models (Elmaghraby and Salem, 1982; Goyal, 1975; Kelley and Walker, 1959; Kelly, 1961; Perera, 1980; Phillips and Dessouky, 1977; Siemens, 1971) and nonlinear programming models (Deckro et al., 1987, 1995; Fulkerson, 1961; Meyer and Shaffer, 1963; Patterson and Huber, 1974). Under the assumption that time and cost tradeoffs for individual activities are linear, the relationship can be represented as a straight line on a graph depicting the relationship between activity time and cost (Wiest and Levy, 1997). The cost of completing the activity varies linearly between the normal time and the crash time (Fulkerson, 1961).

If there is concern over quality degradation then crashing project activities is not desirable, and more time should be allowed to finish the project (Deckro et al., 1995; Vrat and Kriengkrairut, 1986). In such cases, preventive actions should be taken to avoid rework or modifications that might occur during project execution.

Time, cost, and contractor requirements for project management are significant elements for judging the successes of information systems and technology projects (Wateridge, 1998). Once a project has been completed, the time and cost tradeoff problem is no longer an issue for the project manager, and quality or performance becomes key issues (Avots, 1984). The earned quality method assists project managers in detecting the quality variance of project activities, and allows them to take early corrective actions by comparing actual quality with planned quality (Paquin et al., 2000). Project quality is a consequence of the accumulated contributions of all individual activities executed during a project's life cycle.

If the outcome of a project meets or exceeds the project contractor's expectations, the project is deemed successful (Martin and Tate, 2001). The project contractor gives priority to the availability of the outcome in the longer-term perspective, because the project must be profitable. Simply completing the project by the given due date and within budget is not sufficient, because the work must also be of acceptable quality.

Previous research indicates that the quality of project scheduling is not only more important than other factors such as time and cost, but also that it is significant for defining project success. Contractor satisfaction is necessary for success, since the project outcome is transferred to the contractor (Icmeli-Tukel and Rom, 1997).

Linear programming models that simultaneously consider time, cost, and quality were proposed in a previous study (Babu and Suresh, 1996), who explored five different lower bounded constraints for project quality. In an binary integer programming model and the meta-heuristic solution procedure that solves discrete time, cost, and quality tradeoff problems (Tareghian and Taheri, 2006, 2007), the quality level of 0.75–0.99 classified the quality of each project activity. These quality level classifications are theoretically significant, but are inapplicable to real problems, since project contractors do not accept quality degradation. Hence, project planners require mathematical models that are applicable to real problems related to project duration crashing.

3. Proposed mathematical model

Project completion time and cost are affected by the crashing of individual activities. If individual activities are excessively crashed, rework, modifications, or even project failure may occur. Quality checks must be performed immediately after the completion of each individual activity, and corrective actions such as rework or modification can be taken if the quality is not acceptable. The PQLC is needed to execute such corrective actions.

3.1. Problem description

Project costs are generally classified into two categories: the direct costs related to individual activities and the indirect costs related to overhead items. The problem we explore in this paper focuses on individual activities under the assumption that the time–cost tradeoffs for project activities are linear (Swink et al., 2006). The direct costs, considering the PQLC, are minimized under the following assumptions: