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Determining the timing of project control points using a facility location model and simulation

Narjes Sabeghi [a,b,*], Hamed R. Tareghian [a], Erik Demeulemeester [b], Hasan Taheri [c]

[a] Faculty of Mathematical Sciences, Ferdowsi University of Mashhad, Mashhad, Iran
[b] Research Center for Operations Management, Faculty of Business and Economics, Katholieke Universiteit Leuven, Leuven, Belgium
[c] Khayyam University, Mashhad, Iran

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ABSTRACT

Projects are usually performed in relatively unstable environments. As such, changes to the baseline schedules of projects are inevitable. Therefore, project progress needs to be monitored and controlled. The control process can be assumed as a continuum in which one side is continuous control and the other side is no-control. Continuous control and no-control strategies are cost-wise prohibited. Hence, project progress should be controlled at some discrete points in time during the project's duration. The optimal number and timing of control points are the main issues that should be addressed. In this paper, taking a *dynamic view* to the project control, for the first time we use an adapted version of the facility location model (FLM) to find the optimal timing of project control points. Initially, the adapted FLM determines the optimum timing of the control points in the project's duration. A simulation model is then used to predict the possible disruptions in the time period between the beginning of the project and the first control point (*monitoring phase*). If no disruptions are observed, the project's progress is monitored in the second control point, otherwise possible corrective actions are taken using an activity compression model. Whenever due to disruptions, the baseline schedule is to be updated, the FLM is run again to determine the new timing of the control points for the rest of the project's duration. In an iterative manner, this process continues until the timing of the last control point is determined.

1. Introduction

Project success is measured as the ability to complete the project according to the desired specifications, within the specified budget and according to the specified time schedule. However, rarely does a project finish with the same project plan as established in the final stage of the planning phase. Changes to the baseline schedule of projects seem to be inevitable. To complete projects successfully both planning and execution need to be properly implemented. In the absence of a formal process for reviewing and evaluating baseline schedule diversions, the resulting impact will be uncontrolled scope variance. The dynamic environment in which the majority of the projects are performed calls for dynamic control processes. In dynamic approaches, adjustments to the baseline schedule are taken as and when required. As a result, the baseline schedule may change and may require some rescheduling. One objective of the control process may be to minimize the deviations from the baseline schedule. The control process can be assumed as a continuum in which one side is continuous control and the other side is no-control. Continuous control may be the most effective type of project control. However, it is cost-wise prohibitive. Implementing a no-control strategy may also be costly due to the possible penalties imposed on late delivery of the project and other losses due to not being able to deliver the project within the specified criterion. Therefore, a project's progress needs to be controlled at some discrete points in time during the project's duration. The timing of these discrete points (control points) can be specified and fixed prior to the start of the project (*static view*). However, in a dynamic view to control, the timing of control points can be changed during the execution of the project according to the state of the schedule.

In general, there are two approaches to deal with the uncertainty that stems from the dynamism inherent in the scheduling environment, namely proactive and reactive scheduling [6]. Proactive scheduling relies on the statistical knowledge of uncertainty and builds schedules that are less sensitive to project disruptions. Reactive scheduling involves revising a baseline schedule when an unexpected event occurs. In reactive scheduling one may reschedule when schedule diversions occur, either by completely regenerating a new schedule or by repairing an existing baseline schedule. In the current study, the latter view is taken.

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[*] Corresponding author at: Faculty of Mathematical Sciences, Ferdowsi university of Mashhad, Mashhad, Iran.
E-mail address: Sabeghi@stu-mail.um.ac.ir (N. Sabeghi).

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In this paper and in the context of reactive scheduling with a repair strategy, for the first time we adapt a facility location model (FLM) to our purpose of finding the timing of control points. Our solution procedure consists of a computer simulation model combined with an adapted FLM as well as a project crashing model. After determining the first control point using the adapted FLM, the advancement of the project is simulated to predict the types and the magnitudes of deviations from the baseline schedule. In the next phase, using the project crashing model, the necessary adjustment steps are taken (repairing the schedule) to bring the project in line with the baseline schedule as much as possible. In so doing, our objective is to adjust the deviated schedule as soon as possible and also to increase the possibility of meeting the project's due date. The next control points are determined in an iterative manner.

The outline of the paper is as follows. In Section 2, some of the research articles that have dealt with the subject of project control are discussed and where appropriate the commonalities and differences to the current article are mentioned. The proposed method for project control is detailed in Section 3. The results regarding the validity of the method and its performance are given in Section 4. Section 5 concludes by presenting a summary of our study and also provides directions for future research.

2. Literature review

The development of a suitable control system is an important part of the project management effort. Furthermore, it is widely recognized that planning and monitoring play a major role as the cause of project failures. There have been a number of articles, e.g. [1,3,5,7,13,14], published to support the importance of control in the achievement of project objectives. It has been shown that project performance can be improved if appropriate project control systems are in place. Some study by independent project analysis (IPA) identified that an optimal project control approach can reduce the execution schedule slip by as much as 15% [20].

In the following, we briefly discuss some of the research articles that deal with the subject of project control. We categorize our reviews as those articles that deal somehow with the determination of the optimal timing of control points and those articles that deal with more general aspects of project control.

Note that, because the novel part of the current study (determining the timing of control points) falls in the first category, where appropriate, we elaborate on the commonalities and differences to our present research. The first category includes the following articles.

Partovi and Burton [13] carry out a computer simulation to compare the effectiveness of five control timing policies. The policies considered are no monitoring and control, monitoring and control at equal intervals, end-loaded (which advocates less intensive reviews in the early stages and more frequent reviews towards the completion of the project), front-loaded (which assumes more frequent reviews in the early stages and less reviews towards the completion of the project) and completely random monitoring. The comparison is made with respect to the amount of overrun time and also the amount of crashing effort they require in controlling the project. The results indicate that although there are no significant differences among the policies in the amount of crashing effort spent, the end-loaded policy performs best in preventing time overruns. Note that, in contrast to Partovi et al. who are more concerned with the timing of control points under their five pre-defined control policies, we determine the timing of control points dynamically using a weight function that can be easily utilized to define any types of control policies including those studied by Partovi et al.

Tareghian et al. [16] use *simulation–optimization* to find the optimal number of control points as well as their timing. They use an evolutionary approach to determine the optimal number of control points and implement the so-called *electro-magnetism* in order to expedite the simulation process and to minimize the running cost. Based on a small sample of only five randomly generated projects with complexity indices ranging from 5 to 9, they conclude that the number of control points has an upper bound. In addition, in contrast to the results of Partovi et al., Tareghian et al. show that in the context of their studies, it is more beneficial to place the control points in the early stages of the project's duration. This may be due to the differences in the topology of the networks used in their study.

De Falco and Macchiaroli [3] propose a model for the quantitative determination of the timing of control points. Their approach is based on an effort function which is defined as a non-linear function of the total number of activities that are active at each time interval as well as the total slack time. By quantitative analysis of the effort function, they allocate appropriate control activities throughout the project's duration.

Raz and Erel [14] determine the optimal timing of project control points based on maximizing the amount of information generated by the control points. They describe the amount of information as a function of the intensity of the activities carried out since the last control point. The intensity of the activities being executed at any instant of time during the project's life cycle is determined using typical progress *s-curves*. They develop an optimal solution procedure based on dynamic programming and, for a given number of control points, determine the timing of each control point. In contrast to Raz and Erel, in the current research a dynamic view to the project control is employed. However, similar to the *reporting delay* used by Raz and Erel to refer to the amount of time elapsed since the moment the activity took place, we utilize weighted distances in our method to force the timing of control points nearer to the heavily weighted potential control points (see Section 3).

Golenko-Ginzburg and Laslo [5] deal with the problem of production control in a semi-automated production system. They determine the next control point via simulation utilizing a constant time step. Referring to [5], a somewhat dynamic view to the determination of control points is taken. That is, with the objective of minimizing the number of control points (maximizing the time span between two adjacent control points), at any routine control point, given planned amount of production, planning horizon, actual accumulated amount of production observed at that control point and a chance constraint, the timing of the next control point is determined. Our approach differs in at least two fundamental aspects with the study of Golenko-Ginzburg and Laslo. Firstly, for the sake of convergence, they consider a minimal pre-given time span between two consecutive routine control points. We determine the control points (in our study, we call them potential control points) according to the structure of the project network which better reflects the high risk sections of the project that need more attention. Secondly, when some disruptions occur at a control point and the volume of production observed at that point is below the planned trajectory, they simply adjust the plan by connecting a straight line between the current position and the target position. In our approach, we utilize a crashing model to select the most appropriate combination of activities to be compressed so that the observed delays are possibly adjusted. In addition, every time the baseline schedule is modified to adjust the disruptions, the FLM determines the new timing of control points for the rest of the project, in the light of the current modifications.

The following articles may be classified in the second category. Kogan et al. [7] develop and solve a basic model for determining the optimal amount of control effort that should be invested throughout the life cycle of homogenous projects in a