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A review of analytical models, approaches and decision support tools in project monitoring and control

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Abstract

This paper reviews the problems, approaches and analytical models on project control systems and discusses the possible research extensions. We focused on literature in Earned Value Analysis (EVA), optimization tools, and the design of decision support systems (DSS) that will contribute to helping project managers in planning and controlling under uncertain project environments. The review reveals that further research is essential to develop analytical models using EVA metrics to forecast project performance. It also suggests that DSS should be model driven, function as early warning systems and should be integrated to commercial project management software.

Keywords: Project management; Project monitoring and control; Earned Value Analysis; Decision support systems; Project management software

1. Introduction

Projects are one of the most important components of today's organizations. In almost any firm and sector, organizations are becoming more and more project based. This may be perceived as a consequence of the contemporary management practices that have transformed organizations from hierarchical to more flat ones. As they have receded from a hierarchical and isolated nature, projects have become the medium for inter-departmental or even inter-organizational activities. Another factor that reinforces the rise of projects is the increasing competitive pressure. Competition, becoming fierce day by day, leads the firms to seek excellence in accomplishing the tasks. This pursuit of excellence in management has increased the importance of coordination, monitoring and control functions. From this perspective, project based organizational structures support accomplishing specific purposes/outcomes, focusing on responsibility and authority, ensuring better control and coordination, and facilitating better communication and customer relationships (Meredith and Mantel, 2011).

In order to ensure these gains and the accomplishment of goals even under the threat of various uncertainties (Aytug et al., 2005; Herroelen and Leus, 2005), employing effective project monitoring and controlling systems has become essential in project based organizations (Shtub et al., 2005). Considering this need and importance, in this paper we focus on development of these systems, their content and scope. Specifically, we investigate models and algorithms that will support managerial decision making and constitute the foundations of these systems.

To put formally, a project monitoring and control system works to minimize the deviations from the project plans and consists of identifying and reporting the status of the project, comparing it with the plan, analyzing the deviations, and implementing the appropriate corrective actions. Hence it includes the set of policies, methods and tools that would ensure the achievement of the project targets. An effective system should clearly define the following policies:

(a) monitoring policy: what, how, where, when and by whom to monitor,
(b) intervention and control policy: what, how, where, when and by whom to prevent, intervene and correct.

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Mathematical modeling is one of the means to formulate and analyze these policies. It has been used to investigate various project management problems and literature review papers were published (some of them are by Herroelen (2005), Herroelen and Leus (2005) and Kolisch and Padman, 2001). These reviews cover studies that address a wide range of managerial problems (time scheduling, resource allocation, quality assurance). Project monitoring and control from mathematical modeling perspective, conversely, have not received sufficient scholarly attention. Accordingly, we aim to address this lacuna in the literature. Different from its predecessors, this research presents a review with a narrower scope. A more in-depth analysis of approaches and models on monitoring and control systems is performed. Furthermore, an initiative approach for designing model-driven DSS for effective project monitoring and control is developed, with an emphasis on recent developments and studies.

Current studies on project monitoring and control mainly examine financial control tools and various accounting techniques that managers use to monitor the project outcomes (Rozenes et al., 2006). We will not cover these accounting tools in this review. Instead, we will pay special attention to Earned Value Analysis (EVA), since it is the most widely used managerial control tool in the industry. We will elaborate on analytical aspects of EVA and relevant optimization models. We will give emphasis to the integration of these models into decision support systems (DSS) and project management software. Regarding this specific application area, research areas demanding further effort and promising extensions are explicitly listed.

We organize the review and discussions as follows. First, in Section 2.1, we present existing studies on EVA, as it is widely used in practice. Then, in Section 2.2, we examine the optimization models to set project control decision variables, since these models serve as a basis for DSS design. Afterwards, decision support tools and relevant project management software are discussed in Sections 3 and 4. Finally, in Section 5, we present conclusions and make a summary of future research areas.

2. Literature review

2.1. A widely used managerial control tool: earned value analysis

EVA is a managerial methodology to monitor and control projects and it uses monetary units as a common basis to measure and communicate the progress of a project. It is based on comparing the actual and the budgeted values of the work performed, the time taken and the costs incurred. Hence, time and cost perspectives of a project control system are integrated. Cost and schedule variance are calculated to evaluate the current project progress and also predict the total project cost and duration. We refer the readers to the books (Fleming and Koppelman, 2005; Shtub et al., 2005; Vanhoucke, 2009) for more detailed explanations on the basic principles and metrics.

In practice, EVA has been generally used to measure project performance throughout the life of a project. However, it could also be used in forecasting the resulting project outcomes; specifically to estimate the expected project time and cost using the current status of the project. In this aspect, Vandevoorde and Vanhoucke (2006), and Vanhoucke and Vandevoorde (2007) developed three forecasting methods that are based on EVA metrics and compared them in terms of prediction accuracy. For that purpose, nine scenarios and possible outcomes were considered and Monte-Carlo simulation was employed. In addition, activity sensitivity measures and their relationships with forecasting and use in deciding on project control strategy were investigated (Elshaer, 2013; Vanhoucke, 2010).

In order to improve the prediction performance of EVA, statistical methods could be integrated to the analysis (Lipke et al., 2009; Narbaev and Marco, 2014; Tseng, 2011). In this regard, Caron et al. (2013) followed Bayesian approach and integrated experts' opinions in describing the probability of events. In addition to statistical analysis, learning curves and risk management tools were also combined with EVA. Plaza and Turetken (2009) investigated the effects of learning and developed a spreadsheet based DSS.

Concerning risk management, Pajares and Lopez-Paredes (2011) developed two metrics that support managers in differentiating whether project over-runs are within the expected variability or due to structural deviations. In the case of deviations, decisions on corrective actions become critical. For supporting decision making, Aliverdi et al. (2013) and Acebes et al. (2014) used simulation and statistical control charts. In addition to analysis of risks, hedging against uncertainty is important to achieve project targets. For this purpose, Naeni and Salehipour (2011) modeled percent completions as fuzzy numbers and used fuzzy set theory for estimating project performance.

All the abovementioned studies addressed single project organizations. However, firms invest in many projects and these projects have resource dependencies within the firms. Portfolio management, which aims to choose and manage multiple projects in a way that enhances business strategy and contributes to achieving organizational goals, has become more and more critical in organizations. To assess the performance of the projects in the portfolio, Vitner et al. (2006) combined EVA with a multidimensional control system and used Data Envelopment Analysis (DEA), which is a mathematical approach to evaluate the efficiency of decision making units (DMUs). In the project management context, every project was modeled as a DMU and its efficiency was measured as a weighted sum of its outputs divided by a weighted sum of its inputs (see Farris et al. (2006) to evaluate the performance of engineering design projects using DEA).

Other than examining the use of EVA in forecasting and performance assessments, graphical illustrations of EVA parameters have been widely utilized by project managers before taking control decisions. To illustrate the deviations from plans and emphasize the need of corrective actions, graphical tools could be very helpful (Anbari, 2003; Cioffi, 2005). For this reason, Hazir and Shtub (2011) focused on graphical and tabular presentations of EVA. They questioned the relationship between information presentation format and project control. Monte-Carlo simulation was used to replicate and model the uncertain project environments. This simulation technique was used by other researchers to compare two project tracking methods: top-down or bottom-up