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Monitoring project duration and cost in a construction project by applying statistical quality control charts

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Abstract

The earned value is a leading technique in monitoring and analyzing project performance and project progress. Although, it allows exact measurement of project progress, and can uncover any time and cost deviations from the plan, its capability in reporting accepted level of deviation is not well studied. This study presented an approach to overcome this limitation by applying statistical quality control charts to monitor earned value indices. For this purpose, project time and cost performance indices of a real construction project were monitored regularly on individual control charts. The results were quite promising, and not only competed well against traditional approaches, but also enhanced team's knowledge of project performance. At the end, it was concluded that the proposed approach improves substantially the project controlling scheme and enhances the capability of earned value technique.

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1. Introduction

With increasing number of projects in areas of industry, construction, service, etc., and the complexity of managing and executing projects, the project management knowledge, standards and methods become more and more important. These coupled with the critically of completing projects according to the agreed scope, time and cost, have made the project management to receive special significance during recent years. Earned Value (EV) is a project management technique that measures project progress in an objective manner, and provides an early warning of performance issues, if any (PMI, 2004). EV measures project performance and progress by an integrated management of three most important elements in a project, namely cost, schedule and scope. In summary, EV

provides indices for cost and time performances, and for project completion estimation.

Although being introduced in 2000 in PMBOK® guide (PMI, 2000), the first complete guide on EV appeared in 2005 (PMI, 2005). It is widely accepted and well documented that implementing EV would bring added value to project monitoring scheme (Abba and Niel, 2010; Anbari, 2003; Blanco, 2003; Burke, 2003; Cioffi, 2006; Fleming and Koppelman, 2005; Henderson, 2003, 2004; Jacob, 2003; Jacob and Kane, 2004; Kim, et al., 2003; Lipke, 1999, 2003, 2004; McKim, et al., 2000). Several authors have improved the traditional EV by enhancing its capability in evaluating and monitoring project progress (Moslemi Naeni et al., 2011; Navon, 2005; Vandevenoerde and Vanhoucke, 2005). From these, it is not surprising to see EV has been applied to many different disciplines and projects (Al-Jibouri, 2003; Antvik, 2000; Canepari and Varrone, 1986; Cass, 1998; Christensen and Ferens, 1995, 1996).

In practice, project progress is evaluated by comparing EV indices and estimates against past values, against similar

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projects or according to several criteria (for instance, comparing against 1 and reporting any deviations). However, this evaluation does not usually provide additional information regarding the variation allowed for each index or estimate, provided that the status of that index remains still unchanged. Note that having such information is of interest. For instance, the Schedule Performance Index (SPI) is a measure of conformance of actual progress to schedule, and is usually evaluated by comparing the periodical SPI against 1. Unless SPI deviates from 1, everything seems under control. However, even short deviations may still contain warnings about current or future status of project which may highlight possible needs for corrective actions. Besides, in a high priority project, the small variations (still around value 1) may be more important than a project with a normal priority, however, the traditional approaches of evaluating and monitoring project progress cannot distinguish variations to this extent. In fact, the traditional approaches have not developed accordingly. Therefore, developing appropriate approaches to evaluate and monitor EV indices and estimates such that the associated variations can also be monitored would be valuable. This study targeted this goal and improved the way EV is evaluated and monitored. This includes applying statistical quality control charts to monitor statistically EV indices. Thus, performance and progress variations can also be monitored. The most important outcome of this integrated approach is that even small variations in recorded indices and estimates can be noticed and traced back.

Despite benefits of this integrated approach, research targeting application of statistical methods to enhance EV is less available. Lipke discussed statistical distribution of several cost indices of EV, and discussed a method for approximating the distribution to normal distribution, in case of non-normally distributed data. The studies are important as they try to find out whether normality assumption for the indices is valid (Lipke, 2002, 2004, 2006, 2011). Christensen et al. (2003) also studied statistical distribution of cost data and reported that the data can approximately be normally distributed. Barraza et al. (2004) applied stochastic S-curves to determine forecasted project estimates. Their work included forecasting the project performance by projectizing the actual performance on plan, and by combining it with probability of completion. Later, Barraza and Bueno (2007) introduced a probabilistic project control concept by extending the performance control limit curves to derive an acceptable forecast of final project performance. Here the objective is to not exceed planned budget and schedule risk levels. Neither of these two studies considered statistical monitoring of project performance during its execution. Steyn (2008) also studied the importance of quality in projects but from another point of view, that is he studied a framework for managing quality on several specific projects. The work is more about providing a managerial framework rather than providing an analytical approach. Lipke et al. (2009) discussed forecasting final cost and duration of projects, and proposed confidence interval for this purpose. They verified the reliability of their method by applying it on 12 projects.

To the best of our knowledge, research on monitoring statistically EV indices and estimates is limited to Lipke, and Vaughn (2000), Moslemi Naeni et al. (2011), and to Leu and Lin (2008). Lipke, and Vaughn (2000) monitored several EV indices using statistical quality control charts while assuming the data are normally distributed. Moslemi Naeni et al. (2011) developed fuzzy control charts to monitor several EV indices, and provided a transformation method based on fuzzified indices. Leu and Lin (2008) improved the performance of traditional EV by implementing the statistical quality control charts. They implemented individual control charts (ImR charts) to monitor project performance data, and provided a log transformation method. However they did not perform hypotheses tests to verify auto-correlation among data. In this study, for the purpose of better reflecting the practical situations, such assumptions were replaced by statistical hypotheses tests.

This innovative idea, that is combining EV and statistical quality control charts may improve the capability of EV, and can contribute to a better and more reliable project control. In fact, the study is important as it helps to find important changes in the project time and cost progress in advance. In practice, this would yield to recognizing and understanding the trend behind the project progress (those trends will help us to determine whether the project encounter delay, budget overrun, etc.), even very small trends, those that cannot be recognized if simple approaches are used. In contrast to typical evaluation methods, analyzing data statistically reveals more information, very important especially, for the case of high priority or critical projects.

From these, the major contribution of this study is to develop a practical approach of combining EV and statistical quality control charts to monitor statistically EV indices, and to discover any variations. Among several advantages that the combination may bring, perhaps the most important one is understating behavior of EV indices over time, as it helps in measuring better project's performance and progress. Other contributions of the study lie in the way we applied the statistical quality control charts on project progress data. That is, we did not follow the assumptions other studies took, instead we tested statistically conditions required for developing control charts. As we will see later, the way we transform the non-normally distributed project progress data and how to understand which transformation works better are also contributions of the study. We would like to add to these contributions, application of the proposed approach on real data. From the point of applicability, it should be added that use of two statistical software will help people in charge to get more familiar on how the proposed approach can be applied in practice.

We should note that the proposed approach is limited in which it cannot be applied to auto-correlated data, that is when data are statistically dependent on each other. It is worthy to mention that our approach is not limited to the underlying distributions of project progress data. Thus, as long as the data is independent, the method can be applied to projects, no matter what the underlying distribution is.

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