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An Earned Schedule-based regression model to improve cost estimate at completion

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Abstract

Traditional Earned Value Management (EVM) index-based methods for Cost Estimate at Completion (CEAC) of an ongoing project have been known for their limitations inherent with both the assumption that past EVM data is the best available information and early-stage unreliability.

In an attempt to overcome such limitations, a new CEAC methodology is proposed based on a modified index-based formula predicting expected cost for the remaining work with the Gompertz growth model via nonlinear regression curve fitting. Moreover, the proposed equation accounts for the schedule progress as a factor of cost performance. To this end, it integrates into its equation an Earned Schedule-based factor indicating expected duration at completion. The proposed model shows itself to be more accurate and precise in all early, middle, and late stage estimates than those of four compared traditional index-based formulae.

The developed methodology is a practical tool for Project Managers to better incorporate the progress status into the task of computing CEAC and is a contribution to extending EVM research to better capture the inherent relation between cost and schedule factors.

Keywords: Cost estimate at completion; Earned schedule; Earned Value Management; Regression analysis

1. Introduction

Forecasting project cost at completion is of great importance to project management success. It is a forward looking tool to assist Project Managers (PMs) with the task of making timely and appropriate decisions about cost outcome of their in-progress projects (Fleming and Koppelman, 2006).

For over four decades, Earned Value Management (EVM) has been used to forecast cost at completion. This objective methodology integrates project cost, schedule and scope metrics into a single measurement system. It is widely applied for measuring and analyzing project actual status against its baseline, and for providing estimates of project cost and duration at completion (De Marco and Narbaev, 2013). In particular, EVM is used to compute Cost Estimate at Completion (CEAC), a top-down estimate of the project total cost based on the project's status.

Within the EVM framework, several methods exist to compute CEAC, classified as either index-based (IB) or regression-based techniques (Christensen et al., 1995; Lipke, 2004).

In general, IB methods have an inherent limitation due to their only reliance on past information: they assume that remaining budget is adjusted by a performance index (Fleming and Koppelman, 2006; Kim and Reinschmidt, 2011). The second concern associated with the traditional approach is that it provides unreliable cost forecasts early into a project life because of few available EVM data (Fleming and Koppelman, 2006; Zwikael et al., 2000). In this regard, some studies (Anbari, 2003; Cioffi, 2006; Kim et al., 2003; Lipke, 2004) simplified practical implementation and/or extended applications of IB forecasting methods whereas other researches (e.g., Kim and Reinschmidt, 2011; Lipke et al., 2009; Marshall et al., 2008) employed

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statistics into EVM forecasting system to benefit from deeper analysis to support decision making. Caron et al. (2013), Naeni et al. (2011), and Pajares and Lopez-Paredes (2011) integrated risk management techniques to consider also uncertainty as a potential source of structural change in cost and schedule performance in the project dynamic environment.

With the purpose of overcoming the two mentioned weaknesses of the IB approach and produce more reliable CEAC, regression techniques have been regarded as an alternative to traditional IB methods. Through their curve fitting process, regression techniques improve accuracy of the CEAC, especially as they may use a combination of EVM data with Earned Schedule (ES) data and provide more reliable forecasts early into the project life.

However, reported literature reveals that little advancement has been made in the area of improving reliability of the IB approach via its refinement by regression techniques (Lipke et al., 2009; Marshall et al., 2008; Tracy, 2005). Most studies integrating regression concepts into IB approaches concern U.S. defense projects, which are complex in nature with large budgets and long durations (Christensen et al., 1995; Lipke et al., 2009). In addition, within the EVM framework, available regression-based methods to compute CEAC do not consider schedule progress in cost estimates (Lipke, 2003).

To fill these gaps, a new regression methodology is proposed to provide more reliable CEAC. The developed model overcomes the limitations inherent to traditional IB approaches. In addition, the model regards project schedule as a factor of cost performance and, hence, takes into account the schedule progress, measured via the ES concept, to calculate CEAC. The model equation is a classical IB formula modified with a Gompertz growth model function and it integrates an ES-based factor to indicate the expected completion time used into the model.

The paper is structured as follows. Section 2 frames commonly used IB formulae for CEAC, introduces a regression approach for cost S-curve fitting, and formulates a Gompertz growth model to implement it to the proposed methodology. Section 3 designs the methodology and establishes a framework for evaluating the model and comparing its estimated results with those of IB formulae. In Section 4, we apply the EVM data from nine projects to show application of the proposed model, derive the study results, and present the role of ES in the developed methodology. Section 5 explores the findings of the research and associated implications. Section 6 presents the work contributions in advancing the body of knowledge and draws conclusions and suggestions for future research.

2. Cost estimate at completion methods and framework

2.1. The index-based approach

In the EVM theory and practice, the calculation of CEAC entails summing up two factors (Eq. (1)), namely: the Actual Cost (AC) of performed work at Actual Time (AT) and the estimated cost of the remaining work. The second factor is a difference between the Budget at Completion (BAC) and the Earned Value (EV) adjusted by a Performance Index (PI—a measure of cost efficiency of budgeted resources) (PMI, 2011).

$$\mathrm{CEAC}(x) = \mathrm{AC}(x) + (\mathrm{BAC\text{-}EV}(x))/\mathrm{PI}(x) \quad (1)$$

The choice of a desirable PI depends on the project status and associated risks. Zwikael et al. (2000) relate this choice to premises set by PMs in selecting the PI, from the belief that all past cost deviations cancel into the future so that their projects can be accomplished within the BAC to a pessimistic argument that the deviations will continue at the rate observed so far. PMI (2011) provides four PIs to correct the remaining BAC (Table 1) with different assumptions associated with actual project performance. Among these indexes the most commonly used is the Cost Performance Index (CPI), which assumes that past cost performance is the best available indicator of future cost outcome as a reasonable floor estimate. Anbari (2003) states that an estimate obtained using a product of CPI and Schedule Performance Index (SPI) is an indicator of the overall project health and is a ceiling CEAC to reflect both cost deviation and schedule progress. Fig. 1 presents the EVM metrics addressed above and used in this research.

Since this IB approach only relies on past information, it requires stability of the PI to provide for reliable CEAC. In this regard, previous research carried out on defense projects found that a cumulative value of CPI stabilizes by the time the project is 20% complete and the forecast value does not vary by more than 10% from that point in time to completion. The EVM community received this finding as a rule of thumb and generalized it as being applicable for all types of projects. However, recent studies challenged this finding attributing it to large-scaled and long duration defense and energy projects only (Henderson and Zwikael, 2008; Lipke et al., 2009). They questioned whether the PI stability existed and found that most projects from other industries (e.g., construction, software) with relatively small budgets and short durations achieved the PI stability by the second half portion of the project life.

2.2. The regression-based approach and S-curve fitting

To overcome such limitations of conventional IB techniques, regression-based techniques have been gaining acceptance by practitioners. The main feature of these methods is that they describe a linear or nonlinear statistical relationship between a predictor (input) and response (output) variables through their parameters (Bates and Watts, 1988). Parameters of a regression model represent the behavior of project cost over the whole lifecycle.

Efforts put to apply regression models are greater than those needed for relatively simple IB cost forecasting methods. However, claims have been made that they yield better estimates early in the project life, while the IB approach is likely to be unreliable (Tracy, 2005).

In Project Management, S-curves are used to graphically display cumulative progress of work, expressed in units of costs, labor hours, progress percentage, etc., plotted against time (PMI, 2008). The S-like shape of this curve represents