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Prediction of project outcome The application of statistical methods to earned value management and earned schedule performance indexes

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Abstract

Earned value management (EVM) has provided methods for predicting the final cost for projects. In large part, these methods have not been improved upon since their beginnings and, with one exception, remain unsubstantiated as to accuracy. At the present time, EVM application guidance does not support prediction of final duration for the schedule component of projects.

The objective of this research is to improve the capability of project managers for making informed decisions by providing a reliable forecasting method of the final cost and duration. The method put forth and its evaluation make use of a well established project management method, a recent technique for analyzing schedule performance, and the mathematics of statistics to achieve its purpose – EVM, earned schedule (ES) and statistical prediction and testing methods.

The calculation method proposed was studied using data from 12 projects. The results for both final cost and duration are shown to be sufficiently reliable for general application of the forecasting method. The use of the method is encouraged; it may be applied irrespective of the type of work or cost and duration magnitude of the project.

Keywords: Project management; Earned value management; Earned schedule; Prediction; Forecasting; Statistics

1. Background and overview

Earned value management (EVM) is a method of project management, which facilitates project control and provides support in forecasting final cost. While literature shows that EVM outcome prediction for cost is reasonably reliable for very large United States Department of Defense (USDoD) projects [1–5], it is important for all managers, including those managing low cost, short duration projects, to have reliable forecasting tools. Likewise, having an independent estimation tool for predicting project duration is equally valuable. Significant improvement is needed to expand the utility of cost prediction and, develop the very much desired capability to reliably forecast schedule duration at completion.

Thus, the objective of this paper is to improve the forecasting of project outcomes. With improvement, project managers will have better information for their actions.

The method put forth and its evaluation make use of a well established project management method, a recent technique for analyzing schedule performance, and the mathematics of statistics to achieve its purpose – EVM [6], earned schedule (ES) [7,8], statistical prediction [9] and testing methods [10].

The paper's structure includes a short introduction to EVM, then a brief explanation of ES followed by a description of the statistical methods employed. The

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project data used is characterized; subsequently, the research study is described, including the presentation of results and analysis.

2. Review of earned value management and research

An understanding of EVM is assumed in this paper. For convenience, the terminology EVM uses to portray project status and forecast final cost follows:

PV	planned value
AC	actual cost
EV	earned value
CV	cost variance (CV = EV − AC)
SV	schedule variance (SV = EV − PV)
CPI	cost performance index (CPI = EV/AC)
SPI	schedule performance index (SPI = EV/PV)
BAC	budget at completion (the planned cost of the project)
PMB	performance measurement baseline (the cumulative PV over time)
IEAC	independent estimate at completion (the forecasted final cost)

From the 1990 cancellation of the USDoD project for development of the Navy stealth aircraft, the A-12 Avenger, interest heightened for having a better understanding of EVM. From this interest, several studies were performed regarding the CPI and IEAC, and to a much lesser degree the SPI. Several findings came from these efforts [1–5], summarized as follows:

(1) The result from IEAC = BAC/CPI is a reasonable running estimate of the low value for final cost.
(2) The cumulative value of CPI stabilizes by the time the project is 20% complete. Stability is defined to mean that the final CPI does not vary by more than 0.10 from the value at 20% complete ($CPI_{20\%}$).
(3) The range for final cost is obtainable from finding 2: $IEAC = BAC/(CPI_{20\%} \pm 0.10)$.
(4) The value of CPI tends only to worsen from the point of stability until project completion.

The four research findings above were obtained exclusively from USDoD datasets. They have come to be regarded as being generally applicable [11]. That is, these findings are considered equally applicable to all types of work – construction, defense new system development, and software development, spanning from the extremely large multibillion dollar defense efforts lasting more than a decade to small information technology projects, for instance, of $100,000 requiring less than one year for completion. However, managers of small projects report that they very seldom observe the finding for CPI stability. Without knowledge of the CPI stability behavior for smaller and non USDoD projects, these managers have a limited ability to produce reliable forecasts of project cost outcome.

From a recent publication [12] it is shown that findings 2 and 3, which require stability of CPI at 20% complete, are likely applicable only for extremely large projects of long duration. Thus, it is questionable whether managers of small projects can expect reliable decision information from their use.

3. Introduction to earned schedule

EVM and its indicators of project performance are well known and to some degree their behavior is understood. As previously discussed, there have been several studies of the behavior of CPI and IEAC. However, SPI is a different matter. The EVM schedule indicators, SPI and SV, are not so well studied because they are broadly recognized for failing when projects continue execution past the planned end date. For late finish projects, SPI converges and concludes at the value 1.00 while SV behaves similarly, converging and concluding at 0.00. With this flaw schedule prediction cannot be performed reliably using SPI.

A recent extension to EVM has emerged which provides reliable, useful schedule performance information. The extension is earned schedule (ES) [7]. In brief, the method yields time-based indicators, unlike the cost-based indicators for schedule performance offered by EVM.

Fig. 1 is an illustration for understanding the concept. The ES measure identifies when the amount of EV accrued should have occurred. As depicted by the diagram, this is the point on the PMB where PV equals the EV accrued. The vertical line from the point on the PMB to the time axis determines the "earned" portion of the schedule. The duration from the beginning of the project to the intersection of the time axis is the amount of earned schedule (ES).

While ES could be determined graphically as described previously, the concept becomes much more useful when facilitated as a calculation. ES has two components in its calculation. One is the number of time increments of the PMB for which EV is greater than or equal to PV; this component is termed "C". The second component is "I". The calculation of I is a linear interpolation. From Fig. 1, it is observed that the intersection of the PMB for the condition PV = EV describes a time that does not align exactly on a time increment beginning; it is in-between. The interpolation value is computed using the equation, $I = (EV - PV_C)/(PV_{C+1} - PV_C)$, where C is as described previously. Therefore I is the amount of ES accrued within the increment of the PMB from PV at C to PV at $C + 1$. Thus the schedule duration earned, in equation form, is $ES = C + I$.

As further explanation of the linear interpolation portion of ES, it should be made clear that the I component of ES involves only the final time increment of the calculation. The curve of the PMB is not a defined mathematical function; it is created from the cumulative value of PV at periodic time intervals. Without a mathematical function, interpolation is required to determine the fractional