USING PERFORMANCE INDICES TO EVALUATE THE ESTIMATE AT COMPLETION[1]

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ABSTRACT

The estimated final cost of a defense contract, termed the "Estimate at Completion" (EAC), is a controversial number. In their role as advocates, project managers may be reluctant to support an accurate estimate if the estimate is considered too pessimistic for the project to tolerate. The responsible analyst needs a persuasive tool to defend an accurate, but pessimistic EAC. This paper briefly describes the use of performance indices to assess the accuracy of the EAC. Following a brief review of the generic EAC formula, the paper describes how two performance indices, the Cost Performance Index (CPI) and the To-Complete Performance Index (TCPI), may be used to evaluate the accuracy of the EAC. Examples from the A-12 program are used to illustrate the technique.

INTRODUCTION

Occasionally managers assert that the DOD's Cost/Schedule Control Systems Criteria (C/SCSC) and the related cost management reports are an exercise in futility. One can only speculate on the reasons for this criticism. Perhaps one reason involves the perception of the monthly Cost Performance Report as a confirmation of the known, with no predictive value. Indeed, if the purpose C/SCSC were only to insure the accuracy of performance measurement data, then the critics would be right. To be useful for decision making, performance data must be relevant as will as reliable. Although contractor compliance to C/SCSC establishes the reliability of the database, it does not guarantee its relevance; only responsible analysis will do that.

This paper briefly describes the relevance of performance measurement data. In particular, the focus is the use of performance indices to access the accuracy of the predicted completion cost of a defense contract, termed the "Estimate at Completion" (EAC). Following a brief review of the generic EAC formula, the paper describes how two performance indices, the Cost Performance Index (CPI) and the To-Complete Performance Index (TCPI), may be used to evaluate the accuracy of the EAC.

THE ESTIMATE AT COMPLETION

As indicated by Equation 1, the EAC is defined as the actual costs of the contractual work to date (ACWPc), plus the estimate of costs for the remaining work (BAC – BCWPc). Both direct and indirect costs are included in the calculation. (A more complete description of these terms is available elsewhere [6,7,8]).

$$EAC = ACWPc + (BAC - BCWPc) \quad (1)$$

Basic data elements involved in the EAC formula include ACWP, BCWP, BCWS, and BAC. All are regularly detailed in the cost management report prepared by the contractor. Very briefly, the Actual Cost of Work Performed (ACWP) is the direct and indirect costs incurred and allocable to the contractual effort within a given period of time. Budgeted Cost of Work Scheduled (BCWS) and Budgeted Cost of Work Performed (BCWP) are, respectively, the budgets for work planned to be accomplished and actually accomplished within a given period of time. In Equation 1, the subscript "c" stands for cumulative ACWP and BCWP. The Budget at Completion (BAC) is the total budget of all identified work on the contract.

[1] Christensen, David S (1994). Using performance indices to evaluate the estimate at completion. *Journal of Cost Analysis and Management* (Spring):17-24.

Figure 1 illustrates the relationship between these data elements, and is representative of the typical cost and schedule condition on defense contracts: over-budget and behind schedule. When the actual cost of work exceeds the budgeted cost, an adverse cost variance is identified; when work is accomplished later than planned, an adverse schedule variance is identified. Thus, by regularly measuring BCWS, BCWP, and ACWP, cost and schedule variances are identified, investigated, and hopefully resolved. If schedule and cost problems cannot be resolved, then the simple extrapolation of ACWP to the end of the contract will determine the EAC. If the EAC exceeds the BAC, then an adverse "Variation at Completion" is also identified.

Just how ACWP should be extrapolated to the end of the contract is controversial. Figure 1 suggests that nonlinear extrapolation is appropriate. However, a review of over 25 EAC studies suggests that nonlinear EAC models are not more accurate than the linear models [5][2]. Therefore, despite these nonlinear cumulative cost growth patterns, the forecasted EAC is usually a linear extrapolation of ACWP. As shown in the figure, because the actual costs of the completed work have exceeded the budgets, the budget for the remaining work (BAC – BCWPc) requires an upward adjustment. A "performance index" is typically used to make this adjustment, resulting in the following "index-based" formula:

$$EAC = ACWPc + (BAC - BCWPc) / \text{Performance Index} \quad (2)$$

The performance index is usually a combination of BCWS, BCWP, and ACWP. Because defense contracts are usually behind schedule and over-budget, these performance indices are usually less than one. For example, the SPI is less than one when actual accomplishment (BCWP) is less than planned accomplishment (BCWP). Dividing the budget for the work remaining by an index that is less than one will increase the EAC. The following four equations define the four types of performance indices. The indices can be based on monthly, cumulative, or averaged data.

$$\text{Cost Performance Index (CPI)} = BCWP/ACWP \quad (3)$$

$$\text{Schedule Performance Index (SPI)} = BCWP/BCWS \quad (4)$$

$$\text{Schedule Cost Index (SCI)} = SPI \times CPI \quad (5)$$

$$\text{Composite Index} = w1(SPI) + w2(CPI), \text{ where } w1 + w2 = 1 \quad (6)$$

Regardless of which index is used, the assumption implicit in the EAC formula is that past performance is recurrent and reflective of future performance on the contract. Recently completed research has confirmed the reasonableness of this assumption for the cumulative CPI [3,4]. The next part of this paper will describe the results and implications of this research for assessing the accuracy of the EAC.

EVALUATING THE EAC WITH PERFORMANCE INDICES

As a ratio of the budget of work accomplished to the cost of work accomplished, the CPI measures the efficiency of past performance. For example, a CPI of .67 means that $.67 of work has been accomplished for every dollar spent. Clearly, if this performance continues, the contractual effort will overrun the budget. Based on a comprehensive analysis of 155 contracts extracted from the Defense Acquisition Executive Summary (DAES) database, researchers [3] found that the cumulative CPI does not change by more than ten percent once a contract is twenty percent complete; in most cases, the cumulative CPI only worsens as a contract proceeds to completion. This is true regardless of the type or phase of the defense contract, weapon system, or the military service involved.

[2] More research involving nonlinear EAC models is needed. Ongoing research at the Air Force Institute of technology is exploring this issue.

The stability of the cumulative CPI is significant for two reasons. Both involve evaluating the accuracy of the EAC. First, when the cumulative CPI is used as the performance index in the EAC formula, the resulting EAC has been shown to be a floor to any reasonable range of EACs. EACs computed using CPIs over shorter periods (e.g., 6 months) will likely be smaller than the cumulative CPI, and therefore produce a larger EAC. As a result, Department of Defense 5000.2M [8, Part 16H] now requires the program manager's specific justification when the government's "best" EAC in the DAES report is lower than that calculated using the cumulative CPI.

The cumulative CPI can also be used to evaluate the reasonableness of the contractor's Latest Revised Estimate At Completion (LRE) reported on the cost management report. To evaluate the accuracy of the contractor's LRE, another index is computed, termed the "To-Complete Performance Index (TCPI). As shown in Equation 7, the TCPI is the ratio of work remaining (BAC – BCWPc) to money remaining (BAC – ACWPc):

$$\mathbf{TCPI_{BAC} = (BAC - BCWPc) / (BAC - ACWPc)} \quad (7)$$

The TCPI reveals the level of efficiency required to complete the remaining work within the budgetary goal expressed in the denominator. If the TCPI exceeds the cumulative by more than 10 percent, and the contract is more than twenty percent complete, then the budgetary goal is clearly too optimistic. For example, at the twenty percent completion point, if the TCPI and cumulative CPI were 1.2 and 0.7, respectively, then the contract will almost certainly overrun the BAC because the cumulative CPI will not improve by more than ten percent of its value at the twenty percent completion point.

Because most contracts report the LRE in excess of the BAC, the TCPI is often computed using a more likely budgetary goal, the contractor's LRE:

$$\mathbf{TCPI_{LRE} = (BAC - BCWPc) / (LRE - ACWPc)} \quad (8)$$

Here then is another extremely useful tool for evaluating the reasonableness of the EAC. In this case, the TCPI is computed using the contractor's LRE. If the TCPI using the contractor's LRE exceeds the cumulative CPI by more than ten percent, and the contract is over twenty percent complete, then the LRE is too optimistic. This conclusion is not based on emotion, culture, politics, or any other mitigating factor that often complicates and confuses responsible analysis. Instead, the conclusion is based on an objective analysis of 155 contracts extracted from the DAES database. The sample is sufficiently rich to generalize the results to any C/SCSC-compliant contractor, regardless of the contractor's type, phase, weapon system, or service.

The following example illustrates the application of these techniques to the A-12 Program. The A-12 was canceled in January 1991, in part due to an enormous cost overrun and schedule slippage [2]. Table 1 shows the basic performance data for April 1990 [1]. Note that the contractor was predicting an overrun of $354 million, which is the difference between the BAC and the LRE. Using Equation 8, the $TCPI_{LRE}$ is significantly greater than the cumulative CPI, implying that the contractor's number is too low. In addition, note that the EAC supported by the A-12 Program Office is nearly identical to the EAC that would be computed using a cumulative CPI, implying the government's EAC is also probably too optimistic. Other EACs computed using CPIs averaged through shorter periods are much higher than either the contractor's or the program office's EAC. The largest EAC presented in the table is based on the SCI, a favorite index of many experienced analysts. Because the CPI and SPI are each normally less than one, their product (the SCI) is less than either of the index by itself. Accordingly, the EAC computed using the SCI is quite large.

CONCLUSION

Research has documented the general accuracy of the SCI-based EAC. In fact, all of the procedures described here are relatively well-known by experienced analysts, and have been embedded in popular computer-based analysis packages such as Performance Analyzer [9]. The problem has been one of convincing managers that the resulting analysis was accurate. Hopefully, the research briefly reported here will persuade managers to pay attention to their analysts. Performance measurement data are relevant. Performance reports have predictive value.

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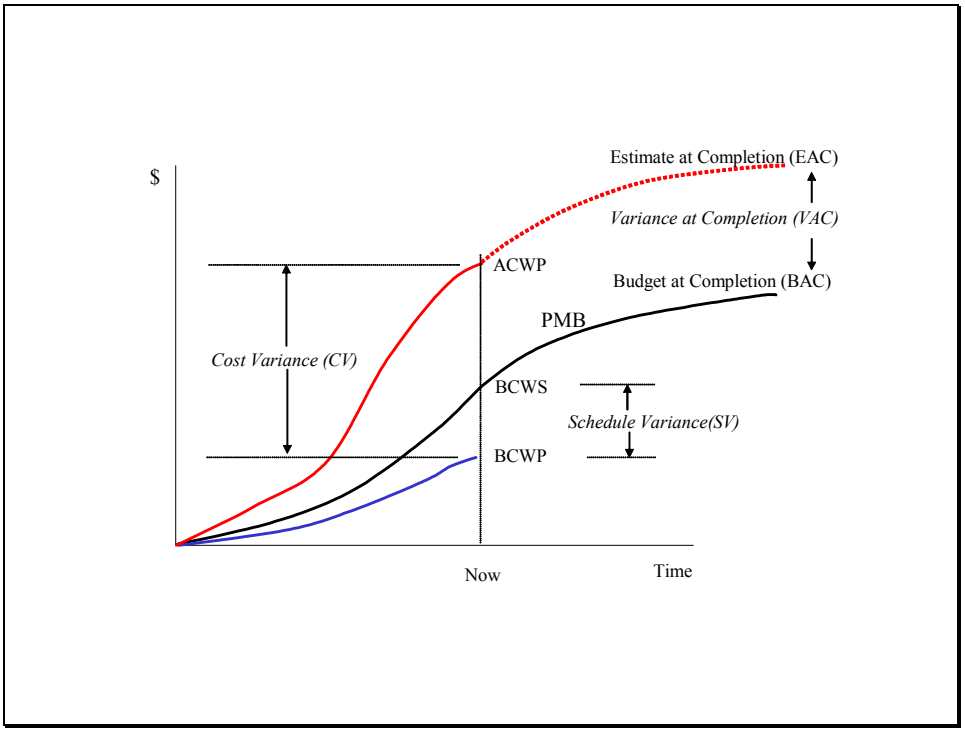

Figure 1. The Estimate At Completion.

TABLE 1
A-12 PERFORMANCE DATA

A-12 CPR Data ($Millions)	**April 1990**
Cumulative BCWS	$2,080
Cumulative BCWP	$1,491
Cumulative ACWP	$1,950
Budget at Completion	$4,046
Contractor's Estimate at Completion	$4,400
Cumulative Cost Variance	$ (459)
Variance at Completion	$ (354)
Performance Indices (Percent)	
Cumulative SPI	71.7%
Cumulative CPI	76.5%
TCPI (based on LRE)	104.3%
Percent Complete	36.9%
Estimates At Completion ($Millions)	
Cumulative Schedule Cost Index (SCIc)	$6,612
Cumulative SPI (SPIc)	$5,514
Composite Index (.5SPIc + .5CPIc)	$5,399
Composite Index (.2SPIc + .8CPIc)	$5,334
Cumulative CPI (CPIc)	$5,292
Government Program Manager's	$5,300