

**IS THE CPI-BASED EAC A LOWER BOUND TO THE
FINAL COST OF POST A-12 CONTRACTS?**

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BIOGRAPHIES

Dr. David Christensen is a Professor of Accounting and Chair of the Department of Accounting and Information Systems at Southern Utah University at Cedar City, Utah. After earning his Ph.D. at the University of Nebraska in 1987, he joined the faculty of the Air Force Institute of Technology, where he taught undergraduate and graduate courses in earned value for over 10 years. Dr. Christensen is a CMA, CGFM, and CCEA and is active in the Society of Cost Estimating and Analysis (SCEA), the American Accounting Association (AAA), and the Institute of Management Accounting (IMA).

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ABSTRACT

Christensen (1994b, 1999) describes several methods to evaluate the predicted final cost of a defense acquisition contract, termed the "Estimate at Completion" (EAC). One of the methods uses the EAC derived from the cumulative Cost Performance Index (CPI) as a lower bound to the final cost of a defense contract. The method was derived from Department of Defense (DOD) experience on hundreds of defense programs completed in the 1970s and 1980s. This study tests the validity of the rule on contracts completed after 1991. Based on an analysis of 52 defense acquisition contracts completed after 1991, the rule is still valid for CPI-based EACs computed in the early and middle stages of a contract, but not valid in the late stage.

BACKGROUND

The cancellation of the Navy's A-12 program in 1991 was a powerful catalyst for change in the defense acquisition community. When Richard Cheney cancelled the A-12 program he complained that no one could tell him the program's final cost (Morrison 1991). Although more realistic estimates were available, a Navy investigation lead by Chester P. Beach (1990) reported that estimates supported by the contractor and the government program offices were too low, and that a more realistic estimate prepared by a senior cost analyst on the A-12 program was suppressed. Beach concluded that similar problems were likely on other defense programs because of an "abiding cultural problem" that suppressed realistic estimates.

In support of his conclusion that the EAC for the A-12 was too low, Beach cited DOD experience with cost growth on hundreds of completed defense programs, wherein the EAC derived from the cumulative CPI was a reasonable lower bound to final cost. Christensen later validated the rule on a large sample of defense acquisition contracts completed in the 1970s and 1980s. In addition, the DOD modified its policy documents to require that any EAC lower than the cumulative CPI-based EAC be specifically justified.¹

The reasonableness of any EAC can be evaluated using three simple techniques:

1. The final cost variance (in dollars or as a percentage) will be worse than the cost variance at the 20% completion point.
2. The cumulative CPI will not change by more than 0.10 from its value at the 20% completion point, and in most cases it only worsens.

3. The EAC computed using the cumulative CPI is a reasonable lower bound to the final cost of a defense contract.

Each rule has been validated by analysis of hundreds of completed defense acquisition contracts (Christensen 1994 1996; Christensen and Heise 1993; Christensen and Payne 1992). When an EAC for a major defense acquisition contract violates any of these rules, the accuracy of the EAC should be questioned. These rules are statistical statements about the mean cost performance of defense contracts. While the cost performance of an individual contract may differ from these rules, it would be a statistical outlier in the sense that its cost performance would be more than two standard deviations away from the mean.²

A recent opinion survey of ten major DOD contractors (Coopers & Lybrand 1997) indicates that current defense acquisition reform initiatives, implemented largely after the A-12 cancellation, are improving the cost performance of defense acquisition contracts. This implies that the EAC evaluation rules may no longer apply, because the evaluation rules predict that cost performance worsens on defense acquisition contracts.³

Christensen and Templin (2001) tested the validity of rules 1 and 2 on post-A-12 contracts (i.e., those started after 1991). The average cumulative cost variance (in dollars or as a percentage) on a sample of 52 post A-12 contracts did not worsen significantly from 20% completion point (rule 1 is not valid), and the cumulative CPI was stable from the 20% completion point (rule 2 is valid). We interpret this result as a signal that cost performance on post A-12 contracts is improving. In this study the validity of rule 3 on post A-12 contracts was tested.

METHODOLOGY

Hypotheses

Null and alternative hypotheses for the CPI-based EAC evaluation rule appear below. If the null hypothesis is rejected, the evaluation rule is confirmed.

Ho:	CPI-based EAC \geq Final Cost	CPI-based EAC is not a lower bound to the EAC
Ha:	CPI-based EAC $<$ Final Cost	CPI-based EAC is a lower bound to the EAC

The rule pertains to the cumulative CPI. The CPI is earned value divided by actual cost, and can be computed based on a single month, an average of several months, or all months to date (cumulative).⁴ When the cumulative CPI is less than one, an adverse cost variance (i.e., a cost overrun) is indicated.

$$\text{CPI} = \frac{\text{Earned Value}}{\text{Actual Cost}} \quad [1]$$

We computed the cumulative CPI at the 20% completion point (CPI20), the 50% completion point (CPI50), and the 70% completion point (CPI70) for each contract in our sample. Percent complete was defined as cumulative earned value divided by the total budget for the planned work on the contract, termed the Budget at Completion (BAC).

$$\text{Percent Complete} = \frac{\text{Cumulative Earned Value}}{\text{BAC}} \quad [2]$$

CPI20 represents cost performance at the early stage of a contract. The 20% completion point was chosen because, in our opinion, earlier performance data are often either not available or considered unreliable. For example, it has sometimes taken over one year for a contractor to be found compliant to the earned value management systems (EVMS) criteria, or to establish a performance measurement baseline (Fleming 1992). Until each is accomplished, performance measurement data are of dubious value. CPI50 and CPI70 represent cost performance at the middle and late stages. Equation 3 shows the equation for the cumulative CPI-based EAC.

$$\text{EAC} = \frac{\text{BAC} - \text{Cumulative Earned Value}}{\text{Cumulative CPI}} + \text{Cumulative Actual Cost} \quad [3]$$

The Database

We collected contract performance data from the Defense Acquisition Executive Summary (DAES) database, maintained by the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD (AT&L)). The database contains cost and schedule performance data on more than 500 completed and on-going contracts from as early as 1971. A contractor prepares a monthly cost performance report (CPR) that summarizes cost and schedule performance, and sends it to the government program office for analysis. The program office summarizes the CPR data into a DAES report that is sent to OUSD (AT&L) for analysis and storage in the DAES database.⁵

The reliability of the data is controlled by a DOD requirement for contractors to comply with Earned Value Management Systems (EVMS) criteria (DOD 1997). The criteria are internal controls intended to encourage adequate planning and control. When the contractor's management control systems are compliant to the EVMS criteria, the government assumes that the performance data are reasonably reliable. In general, contractors that submit the CPR are required to be EVMS criteria-compliant.

The Sample

We identified 52 post A-12 contracts with the necessary data to test the hypotheses. All contracts with the necessary data were included in the sample. The necessary data included values for cumulative earned value, cumulative actual cost, and BAC at the 20% (early), 50% (middle), 70% (late) completion points, and after the 80% completion point. Contracts with unstable budgetary baselines were excluded because the validity of cost performance data on such contracts is seriously impaired.⁶ For the early, middle, and late stages, we selected any contract within plus or minus 5% of that stage. Because many contractors discontinue CPR reporting after the 80% completion point, we defined the final cost as the cumulative actual cost from the last available CPR for each contract, and included it if the percent complete exceeded 80% and we could match it with the same contract at the other stages.⁷

Hypothesis Testing

We tested each hypothesis on the entire sample and on various categories within the sample using the one-sided t test.⁸ To adjust for differences in contract size, the EAC for each contract was normalized into deviation from the final cost (DAC). The average DAC was computed for the entire sample and for various categories of the sample, including contract phase (development, production), contract type (cost-reimbursable, fixed price), and the military service managing the contract (army, air force, navy). The hypothesis was evaluated at the 0.05 level of significance.⁹

$$\text{DAC} = \frac{\text{EAC} - \text{Final Cost}}{\text{Final Cost}} \quad [4]$$

We chose 31 Dec 91, about one year after the A-12 cancellation was announced, as a cut-off date for distinguishing pre A-12 contracts from post A-12 contracts. Any contract starting before 31 Dec 91 was excluded from our sample. We recognize that virtually any cut-off date is arbitrary because the ability of the A-12 cancellation to influence the “abiding cultural problem” described by Beach (1990) could take years. However, we feel this cut-off date is reasonable. The decision to make the CPI-based EAC a lower-bound to any reasonable EAC, for example, was not made DOD policy until after the A-12 cancellation.

RESULTS

As shown in Table 1, the average cumulative CPI-based EAC was significantly lower than the average final cost of the 52 defense acquisition contracts when computed in the early and middle stages of the contracts' lives. In the early stage, the average DAC of -0.107 was significantly less than zero ($p = .001$) for the 52 contracts. In the middle stage, the average DAC of -0.047 was significantly less than zero ($p = .014$). In the late stage, the average DAC was not significantly less than zero ($p = .559$).

Table 1 also shows that the results were sensitive to the category of contract. In the early stage, the average DACs of all categories except fixed price contracts were significantly less than zero. In middle stage, most categories were not significantly less than zero. In the late stage, no category was less than zero. However, these results should be interpreted with caution because of the small sample sizes of the categories.

DISCUSSION

The results show the CPI-based EAC to be a reasonable lower bound to final cost at the early and middle stages of post A-12 contracts. Recent acquisition reform initiatives have not invalidated the evaluation rule. Establishing the CPI-based EAC as a lower bound to final cost is useful to limiting optimistic EACs. Previous research has established that the EACs supported by contractor and government program offices were often too low (Christensen 1994 1996). It seems reasonable that recognizing the CPI-based EAC as a lower bound to any EAC, and making it a DOD policy after the A-12 cancellation, helped to limit the optimism.

The results also show that the CPI-based EAC computed on a contract in the late stage (70% complete) was not a lower bound to final cost, meaning that the average DAC was not significantly less than zero. In the late stage,

the estimation error is likely to be very small because there is less to estimate. Most of the authorized work on the contract is completed and, except for some accounting adjustments, its actual cost is known.

This study has a major limitation. The t test assumes a large, random sample. Our sample consisted of only 52 contracts, and it was not random. Thus, our results may not be true for the population of defense acquisition contracts, especially contracts with unstable baselines. As additional data on completed contracts become available, a study based on a random sample is possible, but this could be many years into the future.

CONCLUSION

Based on our analysis of 52 post A-12 contracts, the CPI-based EAC is a reasonable lower-bound to the final cost of a defense acquisition contract when the EAC is computed in the early or middle stages of a contract's life. In the late stages (70% complete), the CPI-based EAC is not a lower-bound. We suspect the rule has helped to discourage unrealistically low EACs often seen on contracts prior to the A-12 (Christensen 1994 1996). Accordingly, we recommend that the rule continue to be used. The cancellation of the A-12 was a catalyst that helped change a DOD-wide systematic bias toward underestimation (Drezner *et al.* 1993).

Management reluctance to acknowledge a failing project is a widely documented problem in the management literature (e.g., Staw 1981, Chandra, *et al.* 1989). Reasons for this reluctance include a desire to protect the project, the reputation of the project manager, or both. In the A-12 case, Beach (1990) reported that the program manager chose to ignore the expert advice of his own cost analyst and supported an unrealistically low EAC. Beach concluded that the same culture that suppressed the bad news on the A-12 program was a DOD-wide epidemic.

Program managers should certainly listen to their cost analysts, especially when the cost analysts can support their advice with DOD experience on similar contracts. But cost analysts need to recognize the broader decision problems faced by the program managers, who are necessarily advocates of their programs (Gansler 1989). Making the CPI-based EAC evaluation rule a DOD policy was an effective way to limit the program manager's natural desire for an optimistic EAC. The rule also protects the cost analyst from pressure to agree to an unrealistically low EAC.

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TABLE 1
DEVIATION FROM FINAL COST

Contract Category	n	df	Early stage (20% complete)				Middle stage (50% complete)				Late stage (70% complete)			
			mean	stdev	t	p	mean	stdev	t	p	mean	stdev	t	p
All	52	51	-0.107*	0.223	-3.470	0.001	-0.047*	0.148	-2.270	0.014	0.003	0.127	0.149	0.559
Development	24	23	-0.146*	0.238	-3.003	0.003	-0.069*	0.169	-2.000	0.029	0.001	0.145	0.022	0.509
Production	26	25	-0.073*	0.207	-1.806	0.041	-0.018	0.125	-0.752	0.230	0.018	0.095	0.991	0.834
Cost Reimbursable	34	33	-0.144*	0.252	-3.340	0.001	-0.063*	0.167	-2.194	0.018	0.002	0.152	0.068	0.527
Fixed Price	15	14	-0.025	0.145	-0.676	0.255	-0.019	0.112	-0.660	0.260	0.008	0.054	0.592	0.718
Army	14	13	-0.112*	0.221	-1.899	0.040	-0.076	0.187	-1.517	0.077	0.014	0.170	0.298	0.615
AF	12	11	-0.185*	0.242	-2.650	0.011	-0.052	0.146	-1.238	0.121	0.003	0.139	0.083	0.532
Navy	26	25	-0.069	0.215	-1.637	0.057	-0.028	0.129	-1.126	0.135	-0.004	0.095	0.191	0.575

* Significantly less than zero at alpha of .05

¹ The policy was implemented shortly after the A-12 cancellation was announced. It requires the government program manager (PM) to specify a range of estimates at completion, reflecting current, best, and worst cases, in the Defense Acquisition Executive Summary (DAES) report, and to “justify the PM’s best estimate if the contract is at least 15 percent complete and the estimate is lower than that calculated using the cumulative cost performance index” (DOD 2001, 7.15.3g(1)). In addition, the policy requires the servicing cost analysis organization to provide an explanation if the estimate reflecting its best professional judgment is lower than that calculated using the cumulative cost performance index (DOD 2001, 7.15.3g(2)).

² The three evaluation methods were originally developed as rules of thumb by analysts at the Office of the Under Secretary of Defense for Acquisition, Logistics, and Technology. The analysts routinely review the cost and schedule performance of defense acquisition projects from the DAES reports submitted by the military program offices. For a detailed description of how to apply these methods, see Christensen (1994b and 1999).

³ The survey involved a “catalog” of significant acquisition reform measures promulgated since January 1993. The catalog provided a description of 53 “change elements” intended to compress cycle time, reduce program costs, and more effectively leverage commercially available technology and practices. The respondents were asked to indicate the degree of their awareness of each change element, and to estimate its impact from implementation on cost, time, quality, and other factors. There were nine change elements where a majority of respondents estimated “significant” outcomes. The change elements that significantly reduced costs included (1) the use of an “open system approach,” (2) the elimination of military specifications, (3) the use of performance-based requirements, (3) quick prototyping in software development, (4) concurrent testing, and (5) the use of commercial and other exemptions for cost or pricing data (Coopers & Lybrand 1997).

⁴ Earned value, also known as the Budgeted Cost of Work Performed (BCWP), is “the sum of budgets for completed work and completed portions of open work packages, plus the applicable portion of budgets of level of effort and apportioned effort” (DOD 1997,59). For an overview of Earned Value Management Systems (EVMS), including its relevance to project management, see Fleming (1992). Comprehensive web pages to EVMS issues and literature are available at <http://www.acq.osd.mil/pm/>, and <http://www.suu.edu/faculty/christensend/ev-bib.html>.

⁵ The data used in this study are proprietary and cannot be released without the permission of OUSD(AT&L).

⁶ When re-planning of the budget baseline results in a total allocated budget that is greater than the budget for all of the authorized work, the contract is in an "over-target-baseline" (OTB) condition. When this happens, cumulative cost and schedule variances may be eliminated.

⁷ Of the 207 post A-12 completed contracts in the database, 33 (16%) were OTB and excluded from the sample. The requirement for each contract to have performance data at the 20, 50, and 70 percent completion points further reduced the sample to 52 contracts.

⁸ The assumption of normality required by the t-test was evaluated using the Kolmogorov-Smirnov test for normality. The null hypothesis that the sample of DACs is normally distributed could not be rejected at an alpha of 0.05 (Sheshkin 1996).

⁹ Based on Equation 4, the null hypothesis is $DAC \geq 0$. If rejected at an alpha of 0.05, the CPI-based EAC is a lower bound to final cost.