

COST PERFORMANCE INDEX STABILITY- FACT OR FICTION?¹

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INTRODUCTION

The Cost Performance Index (CPI) is a key indicator used to analyze cost/schedule performance data reported by defense contractors. It has long been asserted that the index does not change more than 10 percent once the contract is 50 percent complete [2:1]. A stable CPI is evidence that the contractor's management control systems, particularly the planning, budgeting, and accounting systems, are functioning properly [3,9]. A stable CPI may thus indicate that the contractor's estimated final costs of the authorized work, termed "Estimated at Completion," are reliable. In addition, knowing that the CPI is stable may help the analyst evaluate the capability of a contractor to recover from a cost overrun by comparing the CPI with other key indicators, such as the To-Complete Performance Index [1,7].

A thorough literature search revealed no published study supporting the assertion that the CPI is stable beyond the 50 percent point, although it may have been based on work done by the General Accounting Office in the 1970s. One expert in the cost/schedule performance analysis doubts that the GAO study ever existed [4]. Given the importance of a stable CPI, and the lack of any published evidence supporting the assertion, this study investigates CPI stability.

BACKGROUND

The CPI is one of several indicators used in the evaluation of a contractor's performance. It is calculated from the data that the contractor provides monthly in either the *Cost Performance Report* (CPR) or the *Cost/Schedule Status Report* (C/SSR). DOD Instruction 5000.2 and its related manual (DOD 5000.2M) require that a CPR be submitted for contracts which require compliance with DOD *Cost/Schedule Control System Criteria* (C/SCSC) [5:20-7]. For contracts not required to comply with C/SCSC, the C/SSR is usually required.

C/SCSC is a set of criteria designed to define an adequate contractor cost and schedule management system [6]. The criteria are not a management system. Instead, they describe or establish minimal standards for the management control systems used by the contractor, and have two objectives: (1) for contractors to use effective internal cost and schedule management control systems; and (2) for the Government to be able to rely on timely and auditable data produced by those systems for determining product-oriented contract status [6:v]. Implicit in these objectives is the assumption that if the contractor's management control systems will be reliable. For a detailed description of these criteria, see *The Joint Implementation Guide* [6].

Data summarizing a contract's "product-oriented status" is reported in the CPR or C/SSR. Key elements include *Actual Cost of Work Performed* (ACWP), *Budgeted Cost of Work Scheduled* (BCWS), *Budgeted Cost of Work Performed* (BCWP), *Budget at Completion* (BAC), and *Estimate at Completion* (EAC). It is from these data elements that the CPI and other performance indexes are derived. For a detailed definition of these elements see *The Joint Implementation Guide* [6].

An analysis of these basic data elements provides the government with information having both predictive and feedback value. First, using the basic data elements from a CPR or C/SSR, the analyst can compute an independent EAC for comparison purposes. The reasonableness of the contractor's estimates can thus be assessed by computing independent EACs. Second, through detailed variance analysis the Government is able to continuously identify problems and monitor remedial actions taken by the contractor. As expressed by one Government analyst, an identified problem might not be completely visible, but variance analysis can at least forewarn management of schedule slips and potential cost overruns in enough time to initiate some corrective action [10].

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In the process of transforming the contractor's reported data into information, numerous performance ratios may be computed [7:12-15]. Two ratios important to this study are the *Cost Performance Index* (CPI), and the *Total Complete Performance Index* (TCPI):

$$\text{CPI} = \text{BCWP}/\text{ACWP} \quad (1)$$

$$\text{TCPI} = (\text{BAC}-\text{BCWP}_{\text{cum}}) / (\text{BAC}-\text{ACWP}_{\text{cum}}) \quad (2)$$

The CPI indicates the cost efficiency with which contractual work has been accomplished. A CPI less than one implies a cost overrun; more than one implies a cost under-run; and unity implies an on-target condition. The values for BCWP and ACWP can be monthly, cumulative, or average, as long as they are consistent. The analyst must decide which values to use.

The TCPI represents the efficiency level that the contractor must achieve in the remaining work to meet the budgetary goal. In Equation 2, the budgetary goal is BAC. If the budgetary goal is another number, such as the Contract Budget Base (CBB), then the numerator in Equation 2 should be changed, where CBB is substituted for BAC. The analyst must again decide what budgetary goal is appropriate.

The Importance of a Stable CPI

A stable CPI has relevance to the information generated by the government analyst. First, the CPI is heavily weighted in several of the formulas that generate EACs. One expert claims that the CPI is used in many EAC formulas because of its asserted stability [2:1]. Second, a stable CPI is evidence of criteria-compliant management control systems. For example, if the TCPI is significantly larger than the CPI, the contractor will have to significantly improve the efficiency of the remaining contractual effort. Clearly, if the CPI is stable after a contract is 50 percent complete, and is significantly less than the TCPI, then the 50 percent complete point is too conservative, and suggests that a contractor experiencing a cost overrun at the 15 to 20 percent point will not be able to recover [1].

METHODOLOGY

Hypothesis Testing

The hypothesis tested was: *Once a contract is 50 percent or more complete, the CPI is stable.* CPI stability was defined and measured two ways. First, the range of the CPI was computed maximum CPI achieved after the contract was 50 percent complete. For a given contract, a range of less than .20 defined a stable CPI; otherwise, the CPI was defined as unstable. Second, an interval of plus and minus 10 percent of the CPI computed at the 50 percent point was calculated. For a given contract, a CPI was defined a stable if it stayed within the interval; otherwise, the CPI was defined as unstable. In addition, the sensitivity of the results were tested against earlier points of completion (40, 30, 20, 10, and 0 percent) and narrower intervals (7.5 and 5.0 percent).

The Database

The database used in this study was obtained from the cost library of U.S Air Force Systems Command Aeronautical Systems Division (ASD), and consisted of cost performance data from 26 CPRs for seven aircraft procurement programs. Funding and time constraints restricted the study to seven aircraft programs at ASD that had been "completed." In this study, a completed program (1) had a CPR designated as the final CPR, or (2) was at least 95 percent complete, or (3) was one in which the last aircraft had been delivered. Basic data elements collected from monthly CPRs included BCWS, BCWP, ACWP, BAC, and date (month and year of the CPR). All data elements were taken from the total line of the CPR. Because some of the data are proprietary, the data are not reported in this study.

Five of these seven programs include more than one series of CPRs. The different series of CPRs were needed to capture cost performance data during different phases of the aircraft program. For example, if the program had a separate development phase, there was a separate CPR series for that phase. Table 1 lists the seven aircraft programs included in the database. The table also includes the dates of the initial and final CPR for each CPR series included in the database. The period of performance for these programs ranged from December 1966 to March 1989.

Defining Percent Complete

Changes in CPR reported and contracting philosophy were evident in the CPRs covering these 22 years. Specific differences between programs due to CPR reporting are detailed elsewhere [8]. The differences created a problem in calculating the percent complete for a program. When a program was structured by lot, and there was a separate CPR series for each lot, the monthly percent complete (BCWP/BAC) progressed at an even rate over time. This was because BAC did not change significantly over the life of the lot. However, for programs with only one CPR series, the BAC would change dramatically when additional aircraft were added to the contract. For example, with the addition of new effort, the percent complete in the B-1B Production Program dropped from 67 percent complete to 48 percent complete in one month.

To test the hypothesis, the CPI must be associated with a consistent percent complete, when percent completes allowed to vary with program changes, this consistency is destroyed. Therefore, to ensure consistency, the final BAC from each CPR series was used, and percent complete is defined as follows:

$$\text{Percent Complete} = \text{BCWP}_{\text{cum}} / \text{Final BAC} \quad (3)$$

Of course, the results were checked for sensitivity to this definition. Data for each contract were entered into an electronic spreadsheet. The CPI was calculated using the cumulative BCWP and ACWP according to Equation 1. Percent complete was calculated using the cumulative BCWP and the final BAC according to Equation 3.

RESULTS

CPI Change

As detailed in Table 2, the hypothesis was confirmed. The CPI ranged was stable from the 50 percent completion point. For various levels of percent complete, the table shows the number of contracts found to be stable (*i.e.*, the range was less than .20); the total number of contracts; and the maximum, minimum, mean and standard deviations of the ranges observed. (In going backwards from the 50 percent completion point, the total number of contracts varies because there were some contracts which did not have any observations in the next interval.)

Figure 1 illustrates the same data. For each level of percent complete, the vertical line represents the difference between the maximum and minimum range, and the bottom of the line is located at the value of the minimum range. The horizontal tic mark on each line is located at the value of the mean range. The term “initial percent complete” refers to all those CPIs that lie between the stated percent complete and the end of the contract.

CPI Interval

As detailed in Table 3, the hypothesis was again confirmed. The CPI interval did not change by more than 10 percent from the CPI measured at the 50 percent complete point. The table also shows the number and percentage of contracts with stable CPIs at intervals of 7.5 and 5 percent. Other percent completion points (40, 30, 20, 10, and 0 percent) are also listed.

Analysis

Based on the CPI range test, the CPI was stable (less than .20) for all contracts from the 50 percent point. Sensitivity analysis shows that the CPI was also stable for all contracts from 40, 30, and 20 percent points. At the 10 percent point, the CPI was stable for all but one of the contracts. The assertion of the OSD analyst regarding CPI stability at levels much sooner than 50 percent complete is thus supported.

Based on the CPI interval test, the CPI was stable (+/- 10 percent interval) for all the contracts at the 50 percent point. Sensitivity analysis revealed that all but one contract was stable at tighter intervals (+/- 7.5 percent) at the 50 percent complete point. For the other percent complete points, the percentage of contracts with stable CPI intervals decreases as the percentage complete decreases.

The difference between the CPI range and interval results is attributed to the fact that the CPI interval is centered on the CPI at the 50 percent point. When the CPI that is used to calculate the percentage interval is not exactly centered between the maximum and minimum CPI, a portion of the percentage interval becomes irrelevant. Had the CPI that was used to calculate the percentage interval been centered, the results of the two methods would have been more nearly equal.

Sensitivity to Final BAC

Clearly, the final BAC is not known until the final CPR is received. In practice, the percent complete computation must therefore be based on the most current CPR. To determine if the results were sensitive to the use of a current month percent complete, the CPI range and interval tests were re-accomplished using the BAC at the 50 percent point instead of the final BAC. As detailed in Tables 4 and 5, the results of the CPI range and interval tests were generally insensitive to the percent complete definition.

CONCLUSION

The hypothesis tested was that the CPI is stable after a contract 50 percent complete. CPI stability was defined in terms of CPI range (less than .20) and interval (+/- 10 percent) from the 50 percent completion point. Based on the performance data of 26 CPRs from seven aircraft procurement programs extracted from the ASD cost library, the hypothesis was confirmed. The CPI range was stable from the 20 percent completion point. The CPI interval was stable from the 50 percent completion point.

Knowing that the CPI is Stable is Important

One reason is that the Government can now conclude with some confidence that a contractor is in serious trouble when overrunning the budget beyond the 50 percent complete point. Despite any optimistic claims of the contractor, it is extremely unlikely that a contractor will recover from a cumulative cost overrun after the contract is 50 percent complete, especially if the TCPI exceeds the CPI by more than 10 percent. In fact, results of the sensitivity analysis show that the CPI range is stable as early as the 20 percent complete point.

Of course, the generalizability of these results to other Armed Services or programs are suspect, since the results are based on a database limited to only U.S. Air Force aircraft. Additional research using cost performance data on Army and Navy aircraft, and with other types of programs, such as avionics, engines, or missiles, is continuing at the Air Force Institute of Technology (AFIT).

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TABLE 1**AIRCRAFT PROGRAMS INCLUDED IN STUDY**

	Initial CPR	Final CPR
A-10 program		
ESED	Mar 1973	Aug 1978
Option 1A	Jan 1975	Jul 1977
Option 2A	Sep 1975	Jul 1977
Option 3/4	Jun 1976	Apr 1978
Option 5A	Dec 1976	Apr 1979
Option 6A	Dec 1977	Apr 1980
Option 7A	Jul 1979	Apr 1981
B1-B Program		
Production	Apr 1982	Dec 1989
C-5A Program		
ESED	Feb 1967	Feb 1972
Production	Dec 1966	Feb 1972
C-5B Program		
Production	Oct 1982	Apr 1989
F-111 Program		
RDT&E	Dec 1966	Jul 1973
Production	Nov 1967	Sep 1976
F Model 72-75	Sep 1972	Nov 1975
F Model 74-75	Mar 1974	Feb 1977
F-15 Program		
Thru Wing I	Mar 1970	May 1979
FY 75	Sep 1975	May 1979
FY 76/7T	Sep 1976	Dec 1979
FY 77	May 1977	May 1981
FY 78	Aug 1978	Apr 1982
F-16 Program		
ESED	Jan 1975	Jun 1981
FY 80	Dec 1980	Jul 1982
FY 81	Oct 1981	Jul 1983
FY 83	Oct 1983	Apr 1986
FY 84	Nov 1983	Feb 1989
FY 85	Nov 1984	Jan 1989

TABLE 2**CPI RANGE STABILITY**

	0%	10%	20%	30%	40%	50%
Percent Complete	0%	10%	20%	30%	40%	50%
Total Contracts	19	25	25	25	25	26
Contracts w/ stable CPI	10	24	25	25	25	26
Percent stable	53%	96%	100%	100%	100%	100%
Maximum Range	0.719	0.206	0.163	0.123	0.108	0.093
Minimum Range	0.031	0.030	0.016	0.015	0.015	0.015
Mean Range	0.236	0.092	0.076	0.060	0.052	0.044
Standard Deviation	0.152	0.047	0.042	0.027	0.023	0.019

TABLE 3

CPI INTERVAL STABILITY

	Based on CPI at 50% complete		
Percentage Interval	10.00%	7.50%	5.00%
Number of Contracts	26	26	26
Number of Contracts with Stable CPI	26	25	21
Percent of Contracts with Stable CPI	100%	96%	81%
	Based on CPI at 40% complete		
Percentage Interval	10.00%	7.50%	5.00%
Number of Contracts	25	25	25
Number of Contracts with Stable CPI	24	23	16
Percent of Contracts with Stable CPI	96%	92%	64%
	Based on CPI at 30% complete		
Percentage Interval	10.00%	7.50%	5.00%
Number of Contracts	25	25	25
Number of Contracts with Stable CPI	23	20	14
Percent of Contracts with Stable CPI	92%	80%	56%
	Based on CPI at 20% complete		
Percentage Interval	10.00%	7.50%	5.00%
Number of Contracts	25	25	25
Number of Contracts with Stable CPI	21	17	15
Percent of Contracts with Stable CPI	84%	68%	60%
	Based on CPI at 10 % complete		
Percentage Interval	10.00%	7.50%	5.00%
Number of Contracts	25	25	25
Number of Contracts with Stable CPI	17	15	7
Percent of Contracts with Stable CPI	68%	60%	28%
	Based on CPI at 0% complete		
Percentage Interval	10.00%	7.50%	5.00%
Number of Contracts	19	19	19
Number of Contracts with Stable CPI	7	4	3
Percent of Contracts with Stable CPI	37%	21%	16%

TABLE 4

CPI RANGE STABILITY USING CURRENT MONTH BAC

Percent Complete	50%
Total Contracts	26
Contracts with Stable CPI	26
Percent Stable	100%
Maximum Range	0.093
Minimum Range	0.015
Mean Range	0.047
Standard Deviation	0.020

TABLE 5

CPI INTERVAL USING CURRENT MONTH BAC

Percentage Interval	Based on CPI at 50% complete		
	10.0%	7.5%	5.0%
Number of Contracts	26	26	26
Number of Contracts with Stable CPI	26	25	20
Percent of Contracts with Stable CPI	100.0%	96%	77%

FIGURE 1 CPI RANGE STABILITY

