Why Should CPI = 1?1

Abstract
The expectation when applying Earned Value Management is to control performance such that CPI = 1.00. This paper examines that premise. Two influences are identified: schedule and risk. Each is shown to have negative impact on CPI. Recognizing how the influence is exhibited, an alternative management approach is proposed.

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Introduction
I have wondered from time to time if those who use Earned Value Management (EVM) [PMI, 2005] should rightfully expect the Cost Performance Index (CPI)2 to have a value near or equal to 1.00. Presently project managers (PM) applying EVM desire to guide cost performance such that CPI approaches 1.00. Likewise, those who receive and analyze periodic project status reports examine with a reference of CPI = 1.00. When the value is lower than the specified threshold (for example, CPI = 0.85), an explanation and a planned action for performance improvement is expected as part of the status review. Briefly, this is the EVM system for project cost control. It is the accepted practice.

Nevertheless my question remains, “Is CPI = 1.00 a reasonable expectation?” Commonly during project execution, when the CPI value has been below the specified threshold for an extended time and efforts to cause improvement have not been successful, the PM will request approval to re-baseline the project. By gaining approval from the customer for the re-baseline, the pressure to improve performance is relieved. At least momentarily, the subsequent periodic status reports become acceptable; the CPI threshold has the appearance of not being breached.

This practice diminishes the effectiveness of the EVM methodology for managing the current project and utilizing the measures for future project planning and evaluation of process improvement initiatives. If EVM practitioners could view CPI with an expectation other than 1.00, it may be possible to minimize revising project baselines, thereby preserving project performance history. Additionally, management decisions and corrective actions may improve, as well, with an increased understanding of performance expectations.

The objective of this article is to examine the influences on CPI and propose an analysis/control alternative that improves project management with EVM.

CPI and Schedule
Let us begin with the project plan. During the planning, the potential negative risks are identified and evaluated and the resource loaded schedule is created. Both of these areas will be shown to have negative impact on the expectation for CPI.

Several years ago, I realized that (especially for small projects) the resource loaded schedule may have gaps, potentially causing some of the project personnel to not be fully utilized. For example, let us assume the project schedule requires twelve engineers. However, during a 2-week period, the project only needs ten. Shouldn’t this difference affect the expectation for CPI? Unless two engineers are pooled and shared with another project, they are planned to accrue cost and not have planned value (PV) available to be earned. With this condition known from the outset, the resource cost derived from the planned schedule would be greater than the potential earned value (EV) and thus the expectation for CPI would be a value less than 1.00.

Although not the focus in this discussion, the cost performance efficiency (CPIS) derived from the resource loaded schedule could be used as a measure of scheduling effectiveness. The skills gaps could be evaluated and minimized to create a more efficient and cost effective schedule, indicated by a value of CPIS closer to 1.00.

The value of CPIS, when the schedule is finalized and the project commences, determines the “planned” cost performance efficiency. This cost performance expectation has a maximum value of 1.00. The inefficiency from the schedule gaps affects the management reserve (MR)3 [Humphreys, 2002] needed. The amount of MR to compensate for the gaps is calculable using the following equation:

\[ MR_s = BAC \times (CPIS^{-1} - 1) \]

where BAC is the budget at completion [PMI®, 2005].

CPI and Risk
Over the years there have been initiatives and efforts made to couple EVM and risk management (RM). Some of them are identified here for reference. About five years ago, the NDIA produced survey results indicating there is a strong desire within the EVM community to integrate the two methodologies [NDIA, 2005]. At the 2006 International Integrated Program Management Conference (IPMC), a presentation was made that described

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1 This article was previously published in the March 2011 issue of PM World Today.
2 The CPI = EV / AC, where EV is the earned value and AC is the actual cost.
3 MR is the portion of the project budget that addresses inefficient performance and the negative risk.
The hypothesis that the risk impact distribution is right-skewed as a function of project percentage completed has not been validated. I encourage those with good project data to test and evaluate the idea.

PMB is the time phased planned value from the resource loaded schedule. See Humphreys (2002).

The right-skewed distribution is consistent with previous research, which hypothesized that the distribution may be log-normal (Lipke, 2002).

The hypothesis that the risk impact distribution is right-skewed as a function of project percentage completed has not been validated.
ect progresses through approximately 35% complete. After its peak, the cost of impact decreases to zero at project completion. The integration of the risk graph yields the expected cost for the impacts (known and unknown). If the anticipation of risk is well planned, the MR for the project will be equal to the total expected impact from negative risk. Assuming this is the case for Figure 1, the graph of MR Applied is the integration of the risk occurrence impact.

The CPI plot illustrates a decreasing value with respect to project progress. The CPI is shown to begin at a value equal to 1.00 and ending at 0.77. For this graph it is assumed that risk mitigation efforts are performed outside of the PMB. Thus, for the MR applied to resolve the risks occurring, there is no PV available to earn. For this situation, the CPI can be formulated as follows:

$$CPI = \frac{EV}{(AC_p + ACR)}$$

where $AC_p = \text{actual cost associated with tasks in the PMB}$

$AC_R = \text{cost to mitigate risk not integrated into PMB}$

If the MR strategized for the risk is utilized as expected, $AC_R$ will follow the graph of MR Applied. For the project that executes with perfect cost efficiency for the tasks in the PMB, the CPI is equal to:

$$CPI = \frac{EV}{EV + MRA}$$

where $MRA = MR\text{ Applied (a function of project progress)}$

Examining this equation, it becomes obvious that unless the risk mitigation activities are integrated into the project baseline, CPI must decrease as risks occur. The graph of CPI in Figure 1 was created using this equation. Likewise, the equation allows calculation of the value (0.77) stated earlier for CPI at project completion:

$$CPI = \frac{BAC}{(BAC + 0.3 \cdot BAC)} = \frac{1}{1.30} = 0.77$$

The low value computed for CPI is a direct consequence of the large amount of MR created for the high risk project. This example demonstrates that as project risk becomes high the CPI can be expected to have a final value much lower than 1.00.

**Management Application**

When a fixed CPI threshold for initiating management action is applied, the impact of project risk is not a consideration. For example, the normal EVM practice today is to use the threshold value of 0.90, regardless of whether the project is low or high risk. Because PMs feel compelled to react to CPI values less than the threshold, corrective actions are taken in an effort to increase cost performance efficiency. Especially for high risk projects, these actions may not be worthwhile and could be a detriment.

The plot of CPI in Figure 1 illustrates this point. The value falls below 0.90 early in the project. The PM not having the analysis described in the previous section would react unnecessarily. Because risk impacts continue with project progress, the management invoked improvement actions would not necessarily increase CPI. As conditions worsen, the usual reaction to avert criticism for continuing poor performance is to re-baseline. Generally, the creation of a revised baseline consumes time and diverts effort from performing the project.

The graph shown in Figure 1 for CPI is an outcome of the project plan and its anticipation of risk. The “planned” CPI as a function of project progress may be used for comparison to the actual value. It is a more reasonable comparison than the current fixed value (0.90) approach. When the actual CPI is less than the planned value at the status review, then management should investigate for possible causes and take corrective action when appropriate.

This alternative method is proposed to improve management information and decision making. The method should assist in preventing needless investment in efforts to improve cost performance efficiency. Additionally, having an expectation that CPI will decrease as the project progresses should help to avoid project re-baselines, as well. By minimizing management interventions, project histories will improve and become more useful.

**Forecast and Schedule Application**

An interesting point is that it does not make much difference in cost forecast-
ing whether the risk mitigation action is integrated into the PMB. For illustration, I’ll use numbers from previous discussion: MR = 0.3 BAC and CPI = 0.77. When the risk is integrated, the budget for the revised PMB becomes 1.3 BAC. In this instance, the expectation is CPI = 1.00 and the forecast is calculated as follows:

\[
\text{Forecast} = \frac{\text{Project Budget}}{\text{CPI}} = \frac{1.3 \text{ BAC}}{1.00} = 1.3 \text{ BAC}
\]

When the risk mitigation is not integrated, the impact is seen in the CPI (= 0.77). The calculation becomes:

\[
\text{Forecast} = \frac{\text{Project Budget}}{\text{CPI}} = \frac{\text{BAC}}{0.77} = 1.3 \text{ BAC}
\]

Understanding this provides rationale for not expending time revising the PMB. Some managers may be more comfortable with the incorporation of the risk mitigation activities, but it is unnecessary for cost forecasting purposes.

This article has been focused on management of cost performance. Although there is a lack of published experimental evidence, it is reasonable to conjecture that the schedule performance indicator from Earned Schedule, SPI(t)\(^7\), behaves as does CPI with respect to risk impact. The method described for cost is therefore proposed for application, analogously, to schedule management.

Summary
This article questions whether PMs should have an expectation of CPI = 1.00. Two influences are identified that cause CPI to have values less than 1.00: the resource loaded schedule and risk impact. It was shown that when the schedule does not fully use assigned personnel, there is cost without earned value.

The second influence, risk, is postulated to have a right-skewed distribution with respect to project percentage completed. The risk is mitigated by the management reserve. The application of the reserve is shown to accumulate with the occurrence of risk. When the effort expended to mitigate the risk is not integrated to create a revised PMB, the CPI is shown to decrease as the project progresses.

A method of managing cost performance based upon an expectation of worsening CPI is proposed. The method has potential to improve the application of EVM and avoid wasteful management actions.

Final Comment
The idea that the CPI should be expected to be less than 1.00 and continue to decrease throughout the project is unsettling. It is contrary to the application concept of EVM. The underlying argument for the method is that management reaction to inefficient performance, early in the project execution, enhances the possibility of successful correction such that the project meets its planned cost and delivery date.

However, studies have shown decreasing CPI is likely the normal mode of performance. In a study of CPI stability, Dr. David Christensen and Scott Heise (1993) noted that “…the cumulative CPI … usually declined as the contract proceeded to completion.” A more recent study performed by Air Force Major Dennis Jack (2001), specifically tested for improvement in CPI after a project re-baseline. His finding was that CPI tended not to improve: “…we find there is no statistically significant change in cumulative CPI (negative) slope after an OTB\(^8\) intervention.”

The two studies previously cited give credence to the tenet of this paper: risk negatively impacts CPI throughout the project period of performance. With the acceptance of this connection, the application of the CPI-comparison method proposed can be seriously considered. Research is needed to explore, prototype, and validate the ideas and proposed methods from this article. Those possessing good EVM data are challenged to pursue this research topic.

References


\(^7\) SPI(t) = ES / AT, where ES is the earned schedule and AT is the actual time. See Lipke (2009).

\(^8\) The abbreviation OTB is Over Target Baseline. See Humphreys (2002).
Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base. He has over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics. During his tenure, the division achieved several software process improvement milestones, including the coveted SEI/IEEE award for Software Process Achievement. Mr. Lipke has published several articles and presented at conferences, internationally, on the benefits of software process improvement and the application of earned value management and statistical methods to software projects. He is the creator of the technique Earned Schedule, which extracts schedule information from earned value data. Mr. Lipke is a graduate of the USA DoD course for Program Managers. He is a professional engineer with a master’s degree in physics, and is a member of the physics honor society, Sigma Pi Sigma (ΣΠΣ). Lipke achieved distinguished academic honors with the selection to Phi Kappa Phi (PKΦ). During 2007 Mr. Lipke received the PMI® Metrics Specific Interest Group Scholar Award. Also in 2007, he received the PMI® Eric Jenett Award for Project Management Excellence for his leadership role and contribution to project management resulting from his creation of the Earned Schedule method. Mr. Lipke was recently selected for the 2010 Who’s Who in the World.

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<table>
<thead>
<tr>
<th>2011 Public Seminars</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Earned Value Management Systems</strong></td>
</tr>
<tr>
<td>September 7 – 9, 2011</td>
</tr>
<tr>
<td>Boulder, CO</td>
</tr>
<tr>
<td><strong>Project Scheduling</strong></td>
</tr>
<tr>
<td>October 18 – 20, 2011</td>
</tr>
<tr>
<td>Atlanta, GA</td>
</tr>
<tr>
<td><strong>Advanced Earned Value Management Techniques</strong></td>
</tr>
<tr>
<td>July 19 – 21, 2011</td>
</tr>
<tr>
<td>Lake Tahoe, CA</td>
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<tr>
<td>December 6 – 8, 2011</td>
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<td>San Diego</td>
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