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Why Should CPI = 1?

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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.

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)[a] 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_T = 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

[a] The CPI = EV / AC, where EV is the Earned Value and AC is the Actual Cost.

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 paper 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 two 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 (CPI_S) 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 CPI_S closer to 1.00.

The value of CPI_S, 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)[b] [Humphreys, 2002] needed. The amount of MR to compensate for the gaps is calculable using the following equation:

$MR_S = BAC \bullet (CPI_S^{-1} - 1)$ 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

[b] MR is the portion of the project budget that addresses inefficient performance and the negative risk.

EVM community to integrate the two methodologies [NDIA, 2005]. At the 2006 International Integrated Program Management Conference (IPMC) a presentation was made which described the Northrop Grumman EVM and RM process [Tisone, 2006]. A paper published by David Hillson in 2004 developed a method which connected EVM performance to risk management reactions [Hillson, 2004]. In 2007, again at the IPMC, a presentation was made describing an approach to interfacing EVM and RM [Bone, 2007].

One connection between the two management methods is the risk evaluation for a project should directly relate to the creation of its EVM Management Reserve (MR). The MR is intended during project execution to fund the effort needed to mitigate the impact of a risk should it occur. Although the other references identified above imply this connection, only the presentation by Bone explicitly shows the relationship between risk evaluation and the EVM mechanism for risk handling.

The Bone presentation describes a probabilistic approach to understanding exposure to risk. The outcome of the method is the Performance Measurement Baseline (PMB)[c] along with the MR and the schedule reserve. Although the method illustrates the exposure to risk it does not appear quantified in a way management can easily comprehend for decision making. A calculation method is available which could be used to augment the Bone method. This supplemental calculation produces the probability of having a successful project outcome given the amount of the budget allocated to MR and the risk evaluation in terms of cost performance variation [Lipke, 2009]. Having the probability of success enhances the decision choice for selection of the PMB and MR from the Bone process.

An observation from the Bone presentation is that the potential risks are categorized into two areas, known and unknown. For the known category, the method recommends that plans be created and put into action upon occurrence of the specific risk to mitigate impact. The risk action integrates with EVM by removing the necessary funding from MR, merging the risk mitigation plan with the PMB, thereby increasing the BAC and lengthening the project duration (removing a portion of the schedule reserve, as well). Thus, the risk action can be tracked and managed, along with the remainder of the project, using EVM methods.

Presumably the unknown risks are to be handled using the same process with the exception that before action takes place the mitigation is planned. For this instance, some amount of the MR budget is allocated and made available for planning.

Depending upon the size of the action, management may choose to not integrate the mitigation plan with the PMB, but instead perform the necessary work using a portion of the available MR.

[c] PMB is the time phased planned value from the resource loaded schedule. See [Humphreys, 2002].

Possibly, you can begin to see instances where it is problematic to simultaneously handle risk and expect CPI = 1.0. What happens to CPI when unknown risks occur? In the previous paragraph it was stated that MR is consumed and the action may not be integrated with the PMB. In this instance, for both the planning and the mitigation action, the project incurs the cost but no EV is accrued. When this occurs, CPI should be expected to decrease and become a poorer value. It follows then that the present EVM method of control using a set threshold is very likely causing unnecessary management actions and project re-baselines.

Analysis of Risk Impact on CPI

From the Bone presentation, the distribution of possible project outcomes was illustrated to be right-skewed, for both the cost and time dimensions.[d] The distribution is caused by the uncertainty of the occurrence of the risks. Logically extrapolating, it is my hypothesis that the impact of project risks is related to the present status of the project. That is, the risk impact distribution is right skewed with respect to the percentage completion of the project. As an example, the impact of risk increases from zero to a peak at 35 percent complete, then becomes smaller and smaller as the project progresses, and is equal to zero at project completion. Succinctly, the rationale for this risk distribution is that impacts are likely to appear in relationship to specific dependent activities in the schedule. As the project progresses, the number of dependent activities increase to a point and then decrease until project completion.[e]

Assuming the risk distribution follows the hypothesized description, the MR applied to risk mitigation reflects the cumulative impacts. As described previously, when a risk occurs, its pre-planned mitigation can be integrated with the existing PMB. However, when the mitigation is not integrated, the EVM performance index, CPI, will suffer. The cost performance efficiency will decrease as MR is used to fund the cost of addressing the risk; cost will accrue without a commensurate increase in EV.

Figure 1 illustrates the connection between risk occurrence and the CPI. The graphs of cost for risk occurrence and the MR applied are normalized. The risk occurrence is shown as a fraction of its peak value, while the MR applied is graphed as a portion of the total reserve budget. The inset shows that MR is equal to 30 percent of the BAC. The large percentage is indicative of a high risk project.

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

[e] 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.

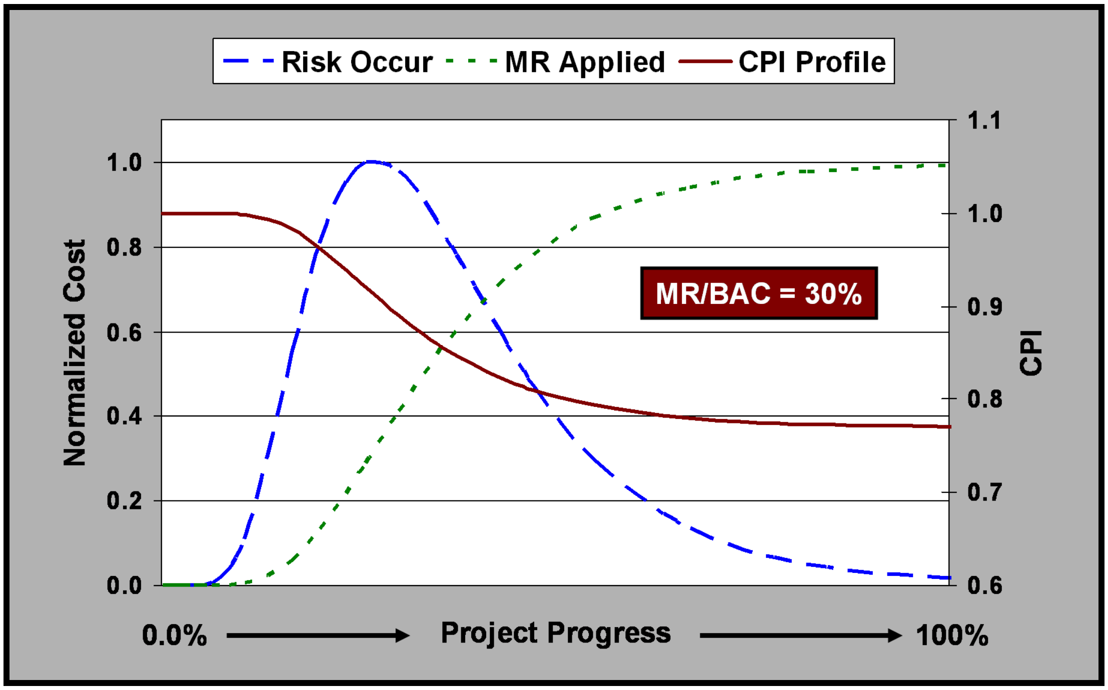

Figure 1. Risk, MR, and CPI

The Risk Occur graph shows the cost of risk impacts increasing as the project progresses through approximately 35 percent 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:

$$CPI = EV / (AC_P + AC_R)$$

where AC_P = actual cost associated with tasks in the PMB
AC_R = 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:

$$CPI = EV / (EV + MR_A)$$

where MR_A = MR 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:

$$CPI = BAC / (BAC + 0.3 \bullet BAC) = 1 / 1.30 = 0.77$$

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 forecasting 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:

Forecast = Project Budget / CPI
= 1.3 BAC / 1.00
= 1.3 BAC

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

Forecast = Project Budget / CPI
= BAC / 0.77
= 1.3 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.

The paper 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)[f], behaves as does CPI with respect to risk impact. The method described for cost is therefore proposed for application, analogously, to schedule management.

Summary

The paper 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

[f] SPI(t) = ES / AT, where ES is the earned schedule and AT is the actual time. See [Lipke, 2009].

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. Dr. David Christensen and Scott Heise noted in a study of CPI stability that "…the cumulative CPI …usually declined as the contract proceeded to completion" [Christensen, 1993]. A more recent study, performed by Air Force Major Dennis Jack, 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[g] intervention" [Jack, 2010].

The two studies cited above 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 paper. Those possessing good EVM data are challenged to pursue this research topic.

[g] The abbreviation OTB is Over Target Baseline. See [Humphreys, 2002].

References

Bone, Lauren, Val Jonas, "Interfacing Earned Value & Risk Management," International Integrated Program Management Conference, November 2007.

Christensen, David S., Scott Heise (1993, Spring). "Cost Performance Index Stability," *National Contract Management Journal*, 1993 (Vol 25): 7-15

Hillson, David, "Earned Value Management and Risk Management: A Practical Synergy," PMI® Global Congress Proceedings, 2004.

Humphreys, Gary, *Project Management Using Earned Value*, Orange, CA: Humphreys & Associates, 2002.

Jack, Dennis E. (Maj), "Contract Over Target Baseline (OTB) Effect On Earned Value Management's Cost Performance Index (CPI), Air Force Institute of Technology Thesis, June 2010

Lipke, Walter H., *Earned Schedule,* Raleigh, NC: Lulu Publishing 2009: 144-150

Lipke, Walt, "A Study of the Normality of the Earned Value Indicators," *The Measurable News*, December 2002: 1-16.

NDIA, "Integrating Risk Management with Earned Value Management," National Defense Industrial Association-Program Management Systems Committee, January 2005.

Project Management Institute, *Practice Standard for Earned Value Management,* Newtown Square, PA: PMI®, 2005.

Tisone, Patti, "Integration of Risk Management and Earned Value Management," International Integrated Program Management Conference, November 2006.

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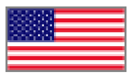

Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base. He has over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics. During his tenure, the division achieved several software process improvement 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 (ΦΚΦ). 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. Mr. Lipke can be contacted at waltlipke@cox.net.