Applying Earned Value and Earned Schedule to Project Management

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Abstract. *When should a manager take action to correct a project not performing well? What should he do if he decides to act? How does a manager know his action is sufficient? These are age-old questions. A poor outcome is a certainty if the manager's decision and action are not appropriate. This paper discusses the questions, and the manager's considerations. It concludes with the description of the decision logic diagram linking project performance with other factors to the possible management actions.*

Introduction

As managers, we worry about delivering a quality product, which performs as the customer expects. It's management's job to guide the project team to meet the negotiated commitment of technical performance, cost, and delivery date. It's tough to do. There are innumerable opportunities for negatively impacting the project throughout the entire period of performance. Several critical elements, such as personnel, facility, data, equipment, material, training, and subcontractors, have the potential to overcome the best of plans. It's not difficult for anyone with project management experience to recall many instances when each one of these elements caused additional cost and consumption of schedule.

To the best of the project team's ability, the risks associated with the critical elements are assessed. Subsequently, reserve in both cost and schedule is created to mitigate the risks foreseen. Oftentimes however, to be competitive, project estimates and reserves are "squeezed," thereby creating a poor situation for the manager from the outset: an aggressive plan with inadequate risk mitigation resources.

In the preceding paragraphs, I have stated the universal dilemma of project management, "Build me a Ferrari on a Yugo budget." Certainly this is a gross overstatement, but as a project manager, it's the way you feel. You understand, very well, from the first day, the probability of success is not 90 percent. It's more likely to be 60 percent, at best. Therefore, a small amount of inefficiency caused by risk impacts will nearly consume the project's reserves.

The execution of the project plan with no variation is the most efficient manner of performance. When changes are made to compensate for critical element impacts, inefficiency is created and some of the reserves are consumed.

Therefore, to judiciously use the reserves, managers must have confidence that the change they induce will have benefit; i.e., the project will have a greater opportunity to complete within the cost and schedule commitment.

The remainder of the paper will create an approach for project analysis and decision-making. The approach will address:

- When a manager should act, and
- What action he should take

A third aspect concerning the sufficiency of the action taken will also be discussed.

Project Management

Performance efficiency is measured by the Earned Value Management (EVM) cost performance index, CPI, and the Earned Schedule (ES) schedule performance index, SPI(t).[1,2] Project managers using EVM and ES in their management practice, thus, have a set of indicators, which provide information concerning the health of their project. If the project is performing at the planned efficiencies (CPI and SPI(t) equal to 1.0), the project is forecast to complete at the planned cost, and deliver its product on the expected delivery date. And, none of the planned reserves for cost or schedule will be consumed.

One method of forecasting whether a project will complete within its funding and negotiated delivery date is to compare the inverse indexes to ratios, which include the cost and schedule reserves.[3] When the value of CPI^{-1} is less than or equal to the cost ratio, the project manager has an expectation that the project will complete within the funding allocated. Correspondingly, if $SPI(t)^{-1}$ is less than the schedule ratio, the project is expected to finish by the negotiated completion date.

Of course, when the inverse indexes are greater than their respective ratios, the project manager knows his project is in trouble. The forecast indicates the plan will be exceeded, the reserves will be consumed, and more resources (time and funding) are needed. Understanding the project is failing, the project manager is inclined to take corrective action. And, certainly the pressures from upper management and the customer compel the project manager to show that corrective action is already in progress.

Why is this the right thing to do? It may not be, but the project manager doesn't have anything in his tool kit to say he should do otherwise. Therefore, being *proactive* is his sole choice. Furthermore, the project manager knows that doing something, right or wrong, will buy time. Wishfully, within that time, a miracle happens and the project gets back on course. If good luck comes his way, the project is "righted," and our hero receives a bonus and maybe even a promotion.

More than likely, the outcome of a reactionary corrective action will not be effective. As mentioned previously, any change to the execution of the plan causes inefficiency. If the action taken is not the correct one, then management has inadvertently worsened the project performance and has not helped the

situation. Subsequently, the manager, being proactive, takes another “shot in the dark,” likely worsening the situation, once again. This process repeats until it becomes obvious to all concerned that the only way to deliver the product is to negotiate additional time and funding. The outcome of this negative spiral is the company and the project manager gain poor reputations. Additionally, if the product is extremely important and its sunk cost is significant with respect to the amount needed for completion, the agitated customer will likely agree to the added cost and delivery date extension. Under these circumstances, the company cannot expect repeat business or future recommendations from this customer.

Another common earned value approach is to manage using the cost variance (CV) percentage; i.e., CV divided by the EV. With this method the project manager takes corrective action upon breaching an arbitrary limit; e.g., plus or minus 10 percent. Generally, the results from the CV management method are as poor as described for CPI.

Certainly, there are successful projects, which have been managed using earned value indicators; we are not implying earned value management has no merit. Using earned value coupled with earned schedule as a project management method greatly increases the opportunity for success, but improvement is needed. Project performance data is readily available, but rarely is it used advantageously. This is the state of today’s management practice.

Analysis & Decision

Is there an alternative? Yes, there is. Simply reacting to poor performance indicators (CPI, SPI(t), or CV) is not good practice. There are other considerations needed to make the management decision. Including the aforementioned indicators of project performance the manager needs information for the following areas:

- Project Performance *Do the indicators show poor project performance?*
- Sufficiency of Data *Is enough data available to make a good decision?*
- Possible Strategy *Can a strategy be created to recover the project?*
- Sufficient Resources *Are there enough resources remaining to use the strategy?*

By doing the analysis, and then answering these questions, a project manager can be confident the decision and action taken will have a much higher probability of success. Before moving on, a few words are needed concerning “Sufficiency of Data.” This information is critical in controlling management’s tendency to overreact. It is common knowledge we shouldn’t react to insufficient data. But, sometimes the pressure to do something is overwhelming and we take action foolishly. Also, once a recovery strategy is implemented, we need to allow it time to be successful. It is not effective to amend and change strategies constantly; in fact, it is wasteful.

Supposing the questions can be answered, and a viable project recovery

strategy can be prepared, *what actions are possible?* There are four basic actions:

- No Action Required ….when *performance is good*
- Investigate ….when there is *insufficient data*
- Adjust/Realign ….*Overtime or Personnel*
- Renegotiate ….*Cost*, *Schedule*, *or Requirements*

Connecting the analysis to the actions is certainly not too difficult for the first two items. When the project is performing well, the manager would be wise to not make any changes. Also, when the project has poor performance, but has insufficient data, it is prudent to investigate for potential causes and simply monitor the indicators for improvement.

The *Adjust/Realign* and *Renegotiate* actions are not so simply connected to the analysis results. The project manager should negotiate additional cost and/or schedule, or reduction of requirements, only when a recovery strategy is not possible, or there is insufficient time for the recovery to be effective. Adjustment, i.e. raising or lowering overtime or number of project personnel, requires several inputs. It is the proper action when performance is poor, there is enough data to make an informed decision, a recovery strategy is possible, and there is sufficient time to execute it.

Careful realignment of personnel can yield increased efficiencies. However, the forecast effects of realignment cannot be quantified easily. It is recommended that this management action be used sparingly. Realignment can be an effective strategy when the values of CPI^{-1} and $SPI(t)^{-1}$ are less than their respective ratios, but worse than their planned value (1.0).

Figure 1, Decision Logic, illustrates coupling the decision data to the management actions. Once the inputs for *Good Performance, Sufficient Data, Satisfactory Recovery Strategy, and Sufficient Resources* are known, the logic diagram can be used to identify the recommended management action.

Conditions	**Criteria**	**Actions**				
Good Performance	$CPI^{-1} \le CR$ $SPI(t)^{-1} \le SR$	O	●	●	●	●
Sufficient Data	$m > 7$	X	●	O	O	O
Satisfactory Recovery Strategy	$CPI_S^{-1} \le CR$ $SPI(t)_S^{-1} \le SR$	X	X	O	O	●
Sufficient Resources	$T\_PI \le 1.0$	X	X	O	●	O
		No Action	**Investigate**	**Adjust**	**Renegotiate**	**Renegotiate**

Legend: O = True, ● = False, **X** = Don't Care

Figure 1. Decision Logic

When the cumulative value of either CPI^{-1} or $SPI(t)^{-1}$ is greater than its respective ratio, the project is performing poorly. Similarly, when there are more than 7 periods of performance data, there is sufficient basis for taking action.[4] The requirement for a recovery strategy is the forecast values of the indexes (CPI_S^{-1} and $SPI(t)_S^{-1}$) at project completion are less than the cost and schedule ratios, respectively.

Developing a possible recovery strategy is a trade-off; improving one index negatively impacts the other [3]. For example, if the problem is poor cost performance, then the strategy, which causes its improvement, will detract from schedule performance, and vice versa. It is also to be noted that the project will experience an added expense to cost and schedule to implement the change.

Once the strategy has been determined, the To Complete Index (T_PI) is used to evaluate whether or not there are sufficient resources for the recovery strategy to be successful.[5] When improvement in schedule performance is the recovery strategy, TSPI is used and, conversely, when the strategy is to improve cost performance TCPI is calculated. We are assured the strategy is viable with a computed value of T_PI less than 1.0. In other words, the project will not have to perform better than planned to achieve the customer commitments.

When the recommended action is either *Adjust*, or *Renegotiate*, management must then determine, "how much?" For *Adjust*, the project manager computes how many people to add or subtract from the project, or how much increase or decrease in overtime is needed to accomplish the recovery. For *Renegotiate*, the manager determines the amount of overrun in cost and schedule. Knowing these values he can then identify the requirements, which can be completed within the remaining time and funding, or the increases to schedule and cost needed to complete all of the requirements. Thus, the project manager has the data with which a contract change may be negotiated.

The calculation methods needed for *Adjust, Renegotiate,* and *Satisfactory Recovery Strategy* are beyond the scope of this paper. The reader may obtain the methods from reference [3].

Lastly, when *Adjust, Investigate,* and *Renegotiate* are simultaneously illogical, the project requires no management action; i.e., *No Action* is appropriate. The input logic for this outcome is depicted in the third column of Figure 1.

Example

To illustrate the use of the Decision Logic diagram (Figure 1), I'll use hypothetical data. Let's suppose for this example the cost ratio (CR) equals 1.2, and the schedule ratio (SR) is 1.3. The reciprocals of the performance index values are 1.250 for CPI^{-1} and 1.125 for $SPI(t)^{-1}$, respectively. The project is 40 percent complete (EV / BAC = 0.4) with 11 months of data.

If the project continues its present performance (CPI^{-1} exceeds CR), it cannot be completed within the project's budget. However, the schedule performance provides some hope. Although schedule performance is not as

good as planned, the project is expected to complete before the customer's delivery date (1.125 < 1.3). Therefore, a possible strategy is computed which elongates the schedule and improves cost efficiency. The possible strategy is determined to be $SPI(t)_S^{-1}$ and CPI_S^{-1} equal to 1.256 and 1.140, respectively. Using the CPI_S^{-1} strategy value (1.140), TCPI is computed to be 0.9375.

With all of the numerical information known, the logical comparisons can be made. We have a "false" for *Good Performance*, CPI^{-1} exceeds CR. *Sufficient Data* is "true," the value of m (11) is greater than 7. "True" is evident for the *Satisfactory Recovery Strategy*, both CPI_S^{-1} and $SPI(t)_S^{-1}$ are less than their respective ratios. And, *Sufficient Resources* is "true," the computed value for TCPI is less than 1.0.

From the evaluation of the logical comparisons, the decision logic diagram is then used to identify the recommended management action. *Investigate* is not an appropriate management action because we have 11 months of data. We have also determined the recovery strategy is possible and there is sufficient time to execute it. Therefore, *Renegotiate* is not the action to use. *Adjust* is the action the logic leads us to. Of course, with *Adjust* selected, *No Action* cannot be the recommended action.

For the *Adjust* action, the manager will perform calculations to determine either a revised overtime or staffing level. If all that is needed is a change in overtime, the success of the project recovery is more certain. Within reason, modifying the overtime level has much fewer repercussions than does changing staffing.

Summary

EVM with ES provides incredible management information. However, it does not provide a good connection between the indicator values and the possible management actions. In today's project management climate, action is more likely to be taken because the project manager perceives it to be the correct thing to do in the eyes of the customer and his superiors.

The Decision Logic diagram (Figure 1) provides the project manager with another tool. Using this tool the method for deciding to take action on a poorly performing project has been significantly refined. Furthermore, the action recommended is the one, which will most benefit the project. The project manager now has a tool he can use effectively for managing his project, and for reporting his actions at the project reviews with both his customer and superiors. Using the decision diagram, he has supporting rationale for his actions.

References

1. Fleming, Q. *Cost/Schedule Control Systems Criteria, The Management Guide to C/SCSC.* Chicago: Probus, 1988.
2. Lipke, W. "Schedule is Different." *The Measurable News*, Summer 2003: 31-34.
3. Lipke, W. "Project Recovery …It Can be Done." *CrossTalk*, January 2002: 26-29.

Notes

1. The definitions of the cost index (CPI) and cost variance (CV) are:

   CPI = EV / AC

   CV = EV – AC

   where AC = Actual Cost

   EV = Earned Value

   For more in-depth explanation of earned value, its indicators and terminology, reference Quentin Fleming's book [1].
2. The Earned Schedule definition of the schedule performance index is:

   SPI(t) = ES / AT

   where AT is the actual period of time from project start to present, and ES is the resultant time associated with the performance measurement baseline (PMB) where PV = EV. A more complete description of ES is developed in reference [2].
3. The definitions of the Cost and Schedule Ratios are as follows:

   Cost Ratio = (BAC + MR) / BAC

   Schedule Ratio = (PD + SR) / PD

   where BAC and MR are the EVM terms, budget at completion and management reserve, respectively. PD is the planned duration and SR is the schedule reserve, measured in units of time.
4. The criteria for data sufficiency is that we must have, at minimum, 50 percent confidence of knowing the true values of the performance indexes, CPI and SPI(t). More than seven periods of performance data are needed for the cumulative quantities of CPI and SPI(t) to meet this requirement. Statistically, the true values are known to the degree that, at minimum, it is 50 percent probable that they are within plus or minus one-fourth of the standard deviation of the periodic index values from their respective cumulative values.
5. The underline space in To Complete Index (T_PI) shown in Figure 1 is to be filled in with either "S" or "C," indicating schedule or cost, respectively. The equations for the To Complete Indexes are as follows:

   $TCPI = (1 - EV\%) / (CPI_S^{-1} - AC\%)$

   where EV% = EV / BAC and AC% = AC / BAC

   $TSPI = (1 - ES\%) / (SPI(t)_S^{-1} - AT\%)$

   where ES% = ES / PD and AT% = AT / PD

About the Author

Walt Lipke retired in 2005 as deputy chief of the Software Division at the Oklahoma City Air Logistics Center. 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:

- 1993 - first Air Force activity to achieve Level 2 of the Software Engineering Institute's Capability Maturity Model® (CMM®)
- 1996 - first software activity in federal service to achieve CMM Level 4 distinction
- 1998 - achieved ISO 9001/TickIT registration
- 1999 - received the 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* (Copyright © 2003 Lipke), 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). He is the recipient of the 2007 PMI Metrics Specific Interest Group Scholar Award.

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