Project Recovery ... It Can be Done

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There are courses of action available to project managers when projects go awry. However, when the management indicators clearly point to project performance problems, their connection to the appropriate action is not easily determined. What action should the project manager take, and to what extent? How can the manager know if the action taken will achieve the desired result? This paper addresses these questions.

Earned value management (EVM) provides project managers with a considerable amount of information concerning the health of their project's performance [1]. The project manager has detailed knowledge of the project's performance baseline, and several choices for assessing the performance status. Among the most common management methods using EVM data is the evaluation of cost variance (CV): the budgeted cost for work performed (BCWP) minus the actual cost for work performed (ACWP); and schedule variance (SV): the BCWP minus the budgeted cost for work scheduled (BCWS). The project manager normally will establish "triggers," or percentages for the variances, which, if exceeded, cause a project review and possible management action.

Within the Oklahoma City Air Logistics Center's (OCALC) Software Division, we prefer using the efficiency indicators of EVM to gauge project status [2]. Of course, these indicators are the cost and schedule performance indexes, CPI and SPI, respectively. CPI is the ratio of BCWP to ACWP, while SPI is the ratio of BCWP to BCWS. Fundamentally, the same information is available from these indicators and the variances, CV and SV.

Regardless of the indicators chosen, the information can be viewed as totals, commonly termed "cumulative," or by time periods such as monthly. The cumulative indicators represent all cost and schedule progress from the project start until the present. The monthly indicators provide information for a specific month, and are very useful for recognizing performance trends, good or bad.

Thus, project managers have information to assist their efforts. What can they do with it? Certainly the objective of the project manager is to use the information to control their project and achieve its cost, schedule, and technical performance requirements. Following these fundamental needs are goals for customer satisfaction, company profit, and employee rewards. There is a lot at stake and a considerable amount of pressure to do the job well.

> *"... determining the management action ... is not simple; it is not all that easy to realign employees to maximize efficiency, or to remove inefficient workers."*

Project Control

When the project performance is not as good as expected, or needed, four management actions are possible:

1. The level of overtime or number of employees on the project can be raised or lowered.
2. Employees can be realigned to increase the efficiency of the project.
3. The performance requirements of the project can be reduced.
4. Additional funding and (or) schedule can be added to the project.

Normally, actions one and two are within the project manager's prerogative; he/she can adjust overtime, change the staffing, and realign personnel. Actions three and four, however, usually require negotiation. These actions involve higher management and components of the organization (e.g., contracting), which are beyond the project manager's control. Certainly, actions three and four are appropriate when the situation warrants, but they have the potential to be damaging to all concerned: company, customer, project manager, and the employees. Future business is at risk when customers are informed the product cannot be delivered at the original price and schedule. Re-negotiation with an agitated customer is not a pleasant experience.

The manager that can keep the project moving towards its objectives, thereby avoiding re-negotiation, is a successful one. Skillful employment of available staff and overtime are critical to a positive project outcome. These observations are intuitive. However, to effectively choose between the possible management actions and appropriately control staffing and overtime, the following questions require answers:

1. How does the project manager determine what type of recovery action is appropriate?
2. Once determined, what should be the extent of the action?
3. How does the project manager know if the determined action is achievable and is not an overreaction?

The remainder of this article responds to these questions. The majority of the discussion is focused on question three.

The Basics

As mentioned earlier, using the SPI and CPI cumulative values is the normal management practice within the OCALC Software Division. When the SPI and (or) CPI indicates poor performance, the pairing of the indicators leads to a management action [2]. If the action is to adjust overtime or number of employees, the equations provided in Figure 1 (see page 27) are then used. The result of the calculation is the staffing or overtime necessary to correct the performance for achieving the project plan.

Take note of the "Band the Recovery" words in Figure 1. The minimum action required to achieve customer needs occurs when all of the management reserve is consumed. The expectation is for management reserve to be totally consumed when the value of cost ratio (CR), or schedule ratio (SR), is used in the calculation[1] [2]. With the results of the two calculations, the project manager has the potential maximum and minimum responses to the problem; he/she can then select a performance correction approach between the extremes.

To this point, determining the management action and adjustments appears to be relatively simple. If we want to recover schedule, we must add staff or (and) increase overtime. If we want to improve cost performance, we must realign and (or) decrease staff. It may not be complex, but this is not "simple;" it is not all that easy to realign employees to maximize efficiency, or to remove inefficient workers. It is a tough situation that requires great inter-personal skills. These are the moments in a project when being a project manger is not much fun.

Also, once poor performance has been established there is very little chance of getting the project back on track with the performance baseline. It is certainly not easy to break this news to upper management, either. However, we must accept that the budget at completion (BAC), the planned completion date, and cost of the project, will be exceeded. And, unless a miracle occurs, i.e., the project achieves real performance efficiency improvements, our efforts to "control" the project will cause some consumption of the management reserve. Recovery is not free; schedule recovery will increase cost, and improving cost efficiency will lengthen schedule.

Schedule Recovery (Reserve Funding is used)

$E_{RS} = (SPI^{-1} / TCSI^{-1}) E_a$,

where Ea = Effective level of staffing

$OT_{RS} = (SPI^{-1} / TCSI^{-1}) \cdot (1 + OT_a) - 1$

where TCSI = [1.0 – (BCWP/BAC)] / [1.0 – (BCWS/BAC)]

Cost Recovery (Schedule Reserve is used)

$E_{RC} = (TCPI^{-1} / CPI^{-1}) E_a$

$OT_{RC} = (TCPI^{-1} / CPI^{-1}) \cdot (1 + OT_a) - 1$

where TCPI = [1.0 – (BCWP/BAC)] / [1.0 – (ACWP/BAC)]

Band the Recovery Strategy

– Substitute CR, or SR (as appropriate), for 1.0 in denominator of To Complete Indices

Figure 1: *Adjusting Overtime and Employees*[2]

Refining the Strategy

The simple use of the SPI and CPI to adjust overtime and staffing described earlier is helpful, but we have not answered question three posed in the section on "Project Control." We don't know if the adjustment is an overreaction, or if it is achievable. By taking action without answering this question, the project manger could be setting the project up for additional problems instead of correcting its performance.

To answer the question, we need to know more. We must be able to determine if implementing a change (overtime, staffing) can correct performance to expected completion within the limits of its management reserve. Presently, managers calculate the estimate at completion (EAC) [1] as a check for cost, but they do not have a comparable calculation for testing the impact of a change to the schedule. As was discussed previously, a change in cost performance impacts schedule performance, and vice versa. However, although we understand there is a relationship between them, we do not have a description that models the behavior.

The Model

This section requires some knowledge of calculus and differential equations. If the reader is unfamiliar with these areas of mathematics, he/she may skip to the end of the section. Near the end of the model section, the reader should review equations five and six before proceeding to the application section. The remainder of the article does not require understanding the derivation of the model.

To begin developing the model, we recognize that a change in cost performance, for example, induces a proportional "negative" change in the schedule performance (and vice versa). We alluded to this fundamental concept earlier in the article; the preceding sentence is, simply, a more mathematical way of stating the observation. Thus, in equation form

$$(1) \quad \Delta c \;\hat{}\; -\Delta s$$

where Δ symbolizes the change in performance with the subscript c denoting cost, and s schedule; the symbol ^ indicates "proportional to." Writing this equation in the terms of the performance indicators, it becomes

$$(CPIr^{-1} - CPI_a^{-1}) \;\hat{}\; -(SPI_r^{-1} - SPIa^{-1})$$

where the subscript r indicates the recovery value, and a is the current (actual) value.

If the project has been executing for a reasonable period of time, the cumulative values of CPI and SPI define a "state" of performance. It is the relationship of the project execution to its plan. The multiplication product of $SPIa^{-1}$ and $CPIa^{-1}$ represents that state of performance. When overtime or staffing changes are made, the state of performance tends to remain as it was; in general, there is inertia to any change. Stated mathematically,

$$(SPI_a^{-1} + \Delta s) * (CPI_a^{-1} + \Delta c) = SPI_a^{-1} * CPI_a^{-1}$$

where the symbol * indicates multiplication.

Assuming the Δ values are not large, then the following relationship is determined

$$(2) \quad (\Delta s / SPI_a^{-1}) + (\Delta c / CPI_a^{-1}) \geq 0$$

Using the equality and rearranging the terms we obtain

$$(3) \quad \Delta s / \Delta c = -SPI_a^{-1} / CPI_a^{-1}$$

Thus, after some algebraic manipulation, it can be deduced from equation three that the assumption made about the "state" of the performance yields our beginning observation, i.e., a change in cost performance induces a proportional negative change in schedule performance, and vice versa" (see equation 1). From the mathematics of calculus, equation (3) can be restated: the slope of the SPI^{-1} versus CPI^{-1} function evaluated at point a is equal to the negative of the ratio:

$$SPI_a^{-1}/CPI_a^{-1}$$

A significant point to understand regarding changing the performance characteristics of a project is that any change induces inefficiency. For example, if people are added to a project to improve schedule performance, even if they are wonderful employees and are skilled at doing the work, they will still require an orientation time to become familiar with their roles and interfaces. Instant performance improvement is not possible.

Also, as the necessary change in performance increases, the amount of inefficiency experienced from implementing the change commensurately increases. To effectively manage the performance change, we need to understand the "principle of diminishing returns." Sometimes, our best course of action is to do nothing with the project performance. For this case, the only option remaining is negotiation.

In previous discussion, we had stated that to recover CPI^{-1} or SPI^{-1} to its planned value of 1.0 is virtually impossible. Mathematically, a description of this relationship, when CPI^{-1} is the indicator to be improved, can be stated in calculus notation as

$$dSPI^{-1} / dCPI^{-1} = -\infty, \text{ as } CPI^{-1} \text{ approaches } 1.0$$

where the symbol ∞ means an infinitely large number, and $dSPI^{-1}/dCPI^{-1}$ is calculus notation for the first derivative of the function SPI^{-1} with respect to the variable CPI^{-1}. The calculus equation describing this relationship is

$$(4) \quad dSPI^{-1} / dCPI^{-1} = -k / (CPI^{-1} - 1.0)$$

(see Note 3)

where k is a constant whose value is determined by evaluating this equation at point a and equating the result to the calculus restatement of equation (3),

$$dSPI^{-1} / dCPI^{-1} = - SPI_a^{-1} / CPI_a^{-1}$$

The constant k is, thus, determined to be

$$k = (CPI_a^{-1} - 1.0) * (SPI_a^{-1} / CPIa^{-1})$$

where, again, the subscript a indicates the values of CPI^{-1} and SPI^{-1} are at point a.

After substituting this expression for k into equation (4), the differential equation is then solved, thereby providing the following result for cost performance recovery (i.e., when CPI^{-1} is poor and SPI^{-1} is satisfactory)

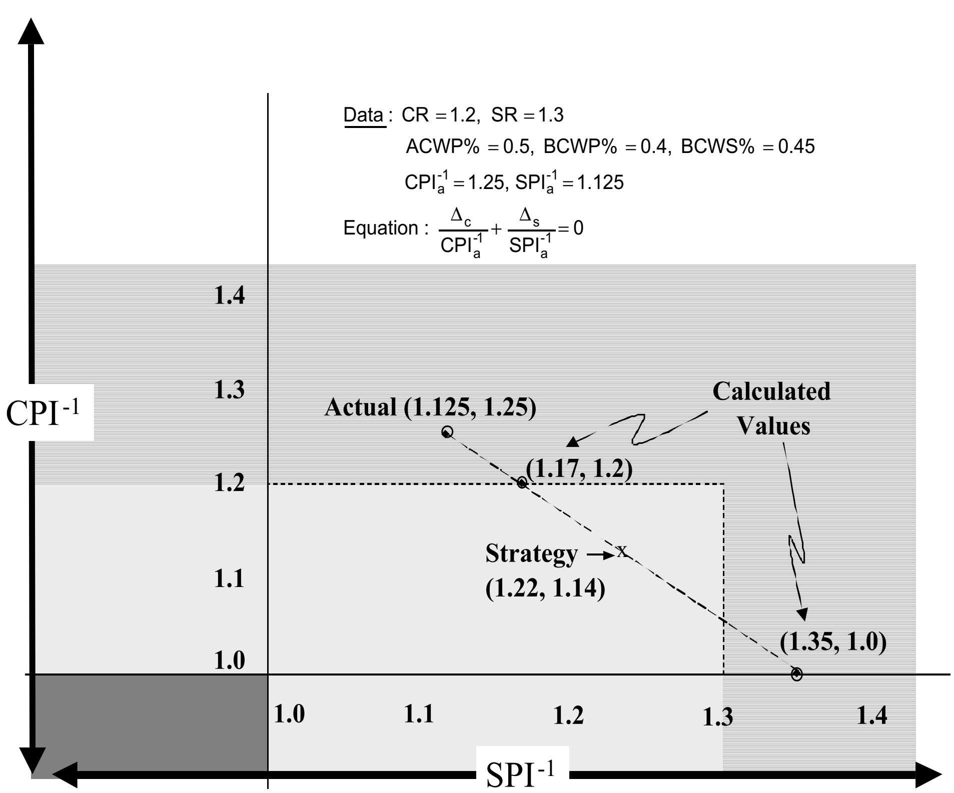
$$(5) \quad SPI_r^{-1} = SPI_a^{-1} + (CPI_a^{-1} - 1.0)\,(SPI_a^{-1} / CPI_a^{-1}) \ln [(CPI_a^{-1} - 1.0) / (CPI_r^{-1} - 1.0)]$$

where ln in the equation is the abbreviation for the natural logarithm, and the subscript r denotes the recovery value.

The equation for schedule performance recovery (when SPI^{-1} is poor and CPI^{-1} is satisfactory) can be analogously determined by simply interchanging CPI^{-1} and SPI^{-1} in the derivation of equation (5). The resultant equation for schedule recovery is

$$(6) \quad CPI_r^{-1} = CPI_a^{-1} + (SPI_a^{-1} - 1.0)\,]\,(CPIa^{-1} / SPI_a^{-1}) \ln [(SPI_a^{-1} - 1.0) / (SPI_r^{-1} - 1.0)]$$

Figure 2: *Project Recovery Example*



Application

To illustrate the use of the recovery equations, we will apply them to an example. For the hypothetical project, we have the following data: CR = 1.2, SR = 1.3, (ACWP/BAC) = 0.5, (BCWP/BAC) = 0.4, (BCWS/BAC) = 0.45. Thus, $CPIa^{-1}$ = 1.250 and $SPIa^{-1}$ = 1.125. Comparing the performance indexes to their respective ratios, we can see that cost performance is poor ($CPIa^{-1} > CR$). While schedule performance is not as planned ($SPIa^{-1} > 1.0$); it is expected to meet the customer requirement ($SPIa^{-1} < SR$). Therefore, our job as a project manager is to improve cost efficiency while retaining satisfactory schedule performance.

The use of equation (5) for determining a cost recovery strategy is not straightforward because the function is logarithmic. One fairly simple method is to make a few calculations for $CPIr^{-1}$ and $SPIr^{-1}$ using the equation, and then graph their coordinates using log-linear graphing paper. Having the graph of the function will then allow selection of a viable recovery value. A viable recovery value is determined when both CPI^{-1} and SPI^{-1} are less than their respective ratio, CR and SR. If no such coordinate can be found, recovery is impossible; negotiation is the only management option remaining.

A much easier graphical approach for identifying viable recovery values is to approximate the SPI^{-1} and CPI^{-1} relationship by using equation (2), i.e., a straight line. For the simple method, two steps are needed. First, the straight-line approximation solution is obtained. A possible viable recovery coordinate is selected, and then it is tested using the logarithmic equation to provide assurance the solution is within the CR and SR values. For our example, solve equation (2) for $SPIr^{-1}$ (see Note 4) to obtain

$$SPIr^{-1} = SPIa^{-1} + (SPIa^{-1} / CPIa^{-1}) * (CPIa^{-1} - CPIr^{-1})$$

Next, substitute the actual values into the above equation and calculate values for $SPIr^{-1}$ corresponding to $CPIr^{-1}$ equal to CR (1.20) and 1.0. Using the results from these calculations along with the actual values a straight line can be plotted as shown by Figure 2.

The selected strategy of $SPIs^{-1}$ = 1.220 with $CPIs^{-1}$ = 1.140 is now tested by using the logarithmic equation. The strategy value of $CPIs^{-1} = 1.140$ is used in the equation to re-compute $SPIs^{-1}$. This computation yields a value of $SPIs^{-1} = 1.256$. Both the selected and computed values of the performance indexes are less than their respective ratios, thus we know the strategy is achievable and is not an overreaction.

Staffing and Overtime Adjustments

Now that we have a recovery strategy for the project, we'll illustrate how it can be used to adjust staffing and overtime. For our hypothetical project, assume we are presently staffed with 20 engineers who are working at 7 percent overtime. Essentially, we will adjust staffing and overtime by using the "To Complete" index corresponding to the recovery strategy.

For cost recovery, the To Complete Performance Index[5] (TCPI) is computed as follows

$$TCPI = [1.0 - (BCWP / BAC)] / [CPI_s^{-1} - (ACWP / BAC)] = [1.0 - 0.4] / [1.14 - 0.5] = 0.9375$$

(see Note 6)

Using the TCPI value, the staffing for the remainder of the project can be determined

$$E_s = (TCPI^{-1} / CPI_a^{-1}) * E_a = (1.067 / 1.25) * 20 = 17.1 \text{ engineers @ 7\% overtime}$$

where E is the number of engineers, and the subscripts s and a indicate the strategy and present values, respectively.

And, similarly overtime can be calculated

$$OT_s = (TCPI^{-1} / CPI_a^{-1}) * (1 + OT_a) - 1.0 = (1.067 / 1.25) * (1.07) - 1.0 = -0.9\% \text{ @ 20 engineers}$$

where OT is the overtime rate. As you can plainly see, reducing overtime for this strategy is not an option; negative overtime is impossible. Therefore, staffing must decrease. We will now re-compute the overtime corresponding to the staffing of 17 engineers

$$OT_s = (17.1 / 17) (1.07) - 1.0 = 7.6\%$$

Thus, the implementation of the recovery strategy is to reduce staffing by three software engineers and increase overtime by 0.6 percent.

Summary

This paper has provided the tools for constructing and implementing a project recovery strategy. A mathematical model of the recovery relationship between the EV indicators, SPI^{-1} and CPI^{-1}, was developed. An application of the relationship was discussed using a cost recovery example. The example illustrates how to obtain a recovery strategy, and then how to translate the strategy into personnel and overtime adjustments. Effective implementation of the adjustments should correct the project performance and result in the achievement of the customer requirements for cost and schedule. Effective, viable, project recovery can be accomplished.◆

References

1. Fleming, Quentin. Cost/Schedule Control Systems Criteria, The Management Guide to C/SCSC. Chicago: Probus 1988.
2. Lipke, Walter H. "Applying Management Reserve to Software Project Management." CrossTalk Mar. 1999.

Notes

1. The cost ratio (CR) is defined as CR = TFA / BAC, where TFA is the total funding available to the project, i.e., BAC plus the management reserve. The schedule ratio (SR) is defined as SR = NPoP / PPoP, where NPoP is the negotiated period of performance and PPoP is the planned period of performance in workdays.
2. The definitions of the abbreviations and subscripts used in Figure 1 are as follows:
   a = actual
   BAC = Budget at Completion
   CR = Cost Ratio
   E = number of employees
   OT = overtime
   RC = cost recovery
   RS = schedule recovery
   SR = Schedule Ratio
   TCPI = To Complete Performance Index
   TCSI = To Complete Schedule Index
3. Equation (4) is not the only mathematical form that becomes infinite as CPI^{-1} approaches 1.0. Because the mathematical relationship may be of another form, the computation results from using the derived equations (5) and (6) should be considered approximations. Other possible mathematical forms have been examined; only very small differences were seen in the computed values of $CPIr^{-1}$ and $SPIr^{-1}$.
4. If instead, schedule recovery were needed, equation 2 would be solved for $CPIr^{-1}$.
5. If the example had required schedule recovery instead of cost recovery, the equation for To Complete Schedule Index (TCSI) would have been used. The equation for TCSI is

$$TCSI = [1.0 - (BCWP / BAC)] / [SPI_s^{-1} - (BCWS / BAC)]$$

6. For recovery to be viable, the calculated value of TCPI (or TCSI, when recovering schedule) should be 1.0 or less. A TCPI greater than 1.0 indicates recovery performance must be better than the plan, which is not a reasonable expectation.

About the Author

Walt Lipke is the deputy chief of the Software Division at the Oklahoma City Air Logistics Center. The division employs approximately 600 people, primarily electronics engineers. He has 30 years of experience in the development, maintenance, and management of software for automated testing of avionics. In 1993 with Lipke's guidance, the Test Program Set (TPS) and Industrial Automation (IA) functions of the division became the first Air Force activity to achieve the Software Engineering Institute's Capability Maturity Model® (CMM®) Level 2. In 1996, these functions became the first software activity in federal service to achieve CMM Level 4 distinction. The TPS and IA functions, under Lipke's direction, became ISO 9001/TickIT registered in 1998. These same functions were honored in 1999 with the Institute of Electrical & Electronics Engineers Computer Society Award for Software Process Achievement. Lipke is a professional engineer with a master's degree in physics.

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