



Applying Management Reserve to Software Project Management

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Today's standard of practice for managing a project's management reserve is an art form. In an effort to make this activity more scientific, the Software Division at the Oklahoma City Air Logistics Center has begun to use an extension of the Cost/Schedule Control Systems Criteria (C/SCSC) [1] technique to manage the reserve components of a software project to achieve the expected completion date and cost.

Since 1985, the Test Program Set (TPS) development activities within the Software Division at the Oklahoma City Air Logistics Center have been performing project management using C/SCSC methods. Initially, the application of C/SCSC management techniques was not thought to be suitable for software. In general, in 1985, only weapons systems program offices involved with major acquisitions employed C/SCSC management. For anything less than a major acquisition, its use was considered to be overly burdensome. However, it was the Software Division's belief that this management system provided advantages over the use of Gantt (milestone) charts that were typical for software projects in 1985. Even today, these charts are extensively used, although the use of earned value is gaining some popularity. The failing with Gantt charts is that managers have no way to connect the outlay of money to the project plan and to the project production; therefore, software managers who use Gantt charts do not have a good understanding of their project's status.

Our initial application of C/SCSC management was crude at best; however, with the performance of several TPS development projects, including the B-1 and B-2 aircraft weapons systems, the methods have evolved and improved and become increasingly more sophisticated. The work breakdown structure (WBS) presently employed bears little resemblance to the one first used in 1985. The earned-value system used today is an order of magnitude more resolute than the system first used in our employment of C/SCSC. Initially, we used only four earned-value elements, regardless of the project requirements; today, we have as few as 10 and as many as 64.

The C/SCSC methods of project management have served the Software Division well. The method is applied at the individual TPS developer level and is aggregated by team lead, total project, and higher organizational levels for various management and customer status reports. Employed in this manner, the method is quite flexible and becomes an extremely powerful management tool. In the 13 years C/SCSC techniques have been used, we have not experienced a single overall TPS development project slippage or cost overrun.

Until a few years ago, our application of C/SCSC project management did not segregate management reserve (MR) into quantifiable management elements. Although the project plan

accounted for the risk in meeting cost and schedule, the MR was integrated into the earned-value system, and thus, its management became unrecognizable. Figure 1 illustrates this point. It shows that the budgeted cost of work scheduled (BCWS) line increases with time until the project completes as planned, indicated by budget at completion (BAC). The difference between BAC and the total project cost and negotiated completion date are the project's MR. As previously explained, our initial application of the C/SCSC method equated BAC to the total project cost and negotiated completion and thereby eliminated the possibility of managing the reserve.

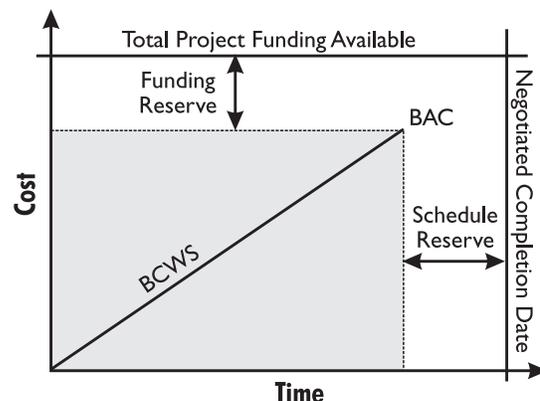
C/SCSC Refresher

A review of C/SCSC terminology and computations will be required to better understand the remainder of this article. The fundamental elements follow. For additional information concerning these formulas and terms, refer to [1].

- BCWS – budgeted cost of work scheduled.
- BCWP – budgeted cost of work performed.
- ACWP – actual cost of work performed.
- BAC – budget at completion.

$$EAC \text{ (estimate at completion)} = ACWP \text{ (cumulative)} + CPI^{-1} [BAC - BCWP \text{ (cumulative)}]$$

Figure 1. Management reserve.



CPI (cost performance index) = $BCWP / ACWP$
 (Greater than 1 is good.)

TCPI (to complete performance index) = $[BAC - BCWP (cumulative)] / [EAC - ACWP (cumulative)]$
 (Greater than 1 is good.)

SPI (schedule performance index) = $BCWP / BCWS$
 (Greater than 1 is good.)

TCSI (to complete schedule index) = $[BAC - BCWS (cumulative)] / [BAC - BCWP (cumulative)]$ (Greater than 1 is good.)

In review, C/SCSC evaluates the calculations of schedule in units of dollars, i.e., cost, rather than in units of time. Figure 2 is an example of a project that is executing behind schedule. Note the Now vertical line. For this example, C/SCSC measures, in units of dollars, the amount project performance lags behind schedule by schedule variance (BCWP – BCWS). Extrapolation of the ACWP line to the calculated EAC value graphically projects cost overrun, e.g., the difference between EAC and BAC. Also, graphical extrapolation of the BCWP line to the BAC value projects schedule slippage in units of time.

Management Reserve Indicators

Some of the desirable yet difficult to develop characteristics considered in the development of the MR indicators and analysis tools were

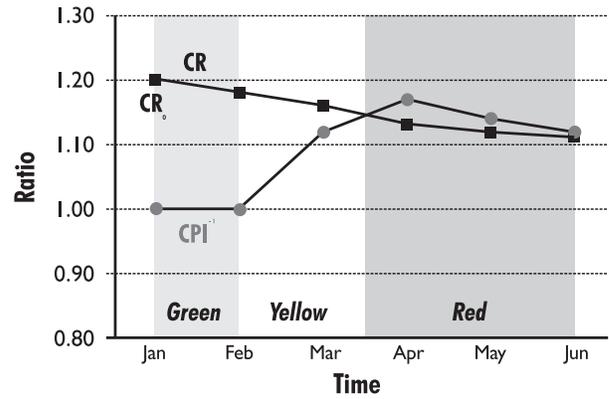
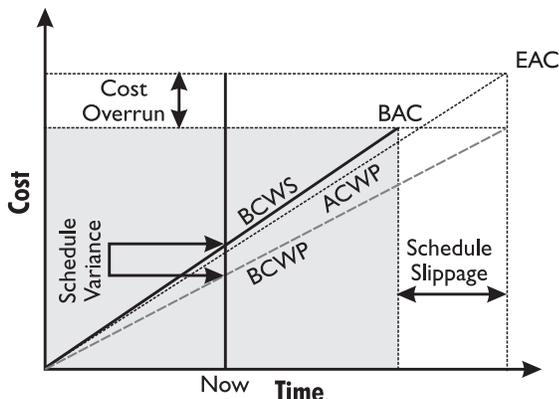
- Similar appearance for each component.
- Simple visual analysis—readily understood “stoplight” (red, yellow, or green) conditions.
- Simple or no project tailoring required.
- Simple calculations.
- Usefulness in project management.

We believe that the indicators and the analysis tools we developed satisfy the above characteristics. The indicators are

- Cost ratio vs. CPI^{-1} .
- Schedule ratio vs. SPI^{-1} .

Cost ratio is total funding available (TFA) for the project divided by BAC, where TFA is the sum of BAC and funding

Figure 2. Cost and schedule analysis.



Green: Project can be completed within planned cost and may have CR remaining. ($CPI^{-1} \leq 1.0$ and $\leq CR$)
 Yellow: Project can be completed within funding available. ($CPI^{-1} > 1.0$ and $\leq CR$)
 Red: Project cannot be completed within funding if present conditions continue. ($CPI^{-1} > CR$)
 (Note: CR varies from CR_0 due to CR used to perform non-WBS activity.)

Figure 3. Cost ratio vs. CPI^{-1} .

reserve. Schedule ratio is negotiated period of performance (NPOP) divided by planned period of performance (PPOP); the difference of NPOP and PPOP is schedule reserve. For clarification, the ratio formulas are

$$\text{Cost Ratio} = \text{TFA} / \text{BAC (dollars)}$$

$$\text{Schedule Ratio} = \text{NPOP} / \text{PPOP (time)}$$

Both the cost and the schedule indices (CPI and SPI) provide information about the cumulative performance of the project at a specific point in time. Also, both indices similarly indicate good performance by a number equal to or greater than one. It was observed that the inverse of the indices could be compared to the corresponding ratios of negotiated vs. planned values for cost and schedule. If the reciprocal of the index value is greater than one, the project manager should be concerned because the project is consuming MR. The level of the manager’s concern can be determined by comparing the index value to the appropriate ratio. If the index value reciprocal exceeds its corresponding ratio, the manager knows the project cannot meet the customer’s expectations without corrective measures.

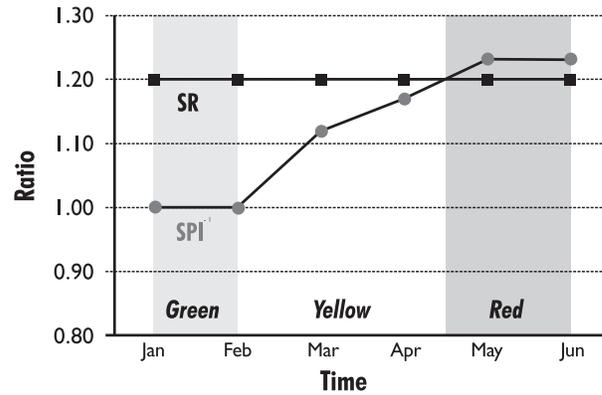
These indicators are graphically portrayed as a time trend (Figures 3 and 4). Conceptually, the graphs of the two indicators are identical. If the project is performing such that CPI^{-1} and SPI^{-1} are less than their respective cost and schedule ratios, the project is in good shape. If this situation continues, the project will complete on time and within the allocated cost. If both CPI^{-1} and SPI^{-1} remain at the value of 1.0, the project is expected to complete as planned—a project perfectly executed.

The differences between the representation of the two indicators are small. The only significant difference is that cost ratio has the possibility of varying, and thus, its initial value is denoted as “CR” with an “o” subscript. The reason cost ratio varies and schedule ratio does not is because of the way C/SCSC accounts for cost and schedule. The use of

schedule reserve is accounted for by expending effort that does not gain earned value, i.e., BCWS marches on with time, but BCWP only does so by increasing earned value. However, cost is a different matter; the use of funding reserve is not reflected in ACWP, BCWS, or BCWP.

A nightmare for software project managers is “extras” thrown at them by the customer. Of course, revised requirements are supposed to be renegotiated and reflected by a revised project baseline that includes a new completion date and changed cost. However, many times the “requirements creep” seems so trivial that project managers forego the perfect practice and merely adjust their funding reserve to account for the change. For many situations, the effort required to re-baseline the project and negotiate the change is far greater than the amount of reserve lost. As an internal practice, we advise customers that changes are being accrued and that we reserve the right to negotiate them once it is apparent the effort to do so is worthwhile; however, until payment occurs for revised requirements, the reduction in funding reserve will be reflected in decreased TFA and thus a lower cost ratio.

Other than the variability of the cost ratio, the graphical appearance and analysis are virtually identical. The conditions to determine the health of the project are simple and easy to recognize. If CPI^{-1} and SPI^{-1} are equal to or less than 1.0, the project can be completed as planned, and the stoplight indicators would be green. And, if the cost of the effort expended for unplanned requirements does not totally consume the funding reserve, some funding is expected to remain at project completion (a project manager’s delight—cash bonuses for everyone on the project). If CPI^{-1} and SPI^{-1} are computed to be between the value of 1.0 and their respective ratios, the stoplight indicator is yellow—the project is not performing as well as anticipated but is still executable (project manager and employees get to keep their jobs). The last condition, i.e., the red indicator, is evident when CPI^{-1} and SPI^{-1} exceed their respective reserve ratios. The project cannot be completed in



Green: Project can be completed within planned time. ($SPI^{-1} \leq 1.0$)
 Yellow: Project can be completed within negotiated time. ($SPI^{-1} > 1.0$ and $\leq SR$)
 Red: Project cannot be completed within negotiated time if present conditions continue. ($SPI^{-1} > SR$)

(Note: SR does not vary. Use of SR for non-WBS activity is accounted for in SPI, i.e., BCWP)

Figure 4. Schedule ratio vs. SPI^{-1} .

the red dimension if the present conditions continue—the negotiated cost or schedule is expected to be exceeded (a bad situation for those involved).

Management Use

The next step is to determine the appropriate management action when conditions are other than green. Managers have a choice of four possible strategies to recover a project:

- Adjust overtime or number of employees.
- Realign employees to increase efficiency.
- Reduce performance requirements.
- Negotiate additional funding or schedule.

Generally, strategies 1 and 2 are within the project manager’s prerogative and are much preferred, whereas strategies 3 and 4 require unpleasant negotiation with the customer. Application of strategies 3 and 4 are to be used as a last resort because they build a negative image that impacts future business with that customer and others who might contact your customer as a reference.

Table 1 aggregates all the combinations of conditions possible for the two indicators and associates each combination with a specific recommended management action. Certainly, for multiyear projects, if both indicators are consistently green, the manager should reward employees—the program has had good planning and good execution. It is worthy to note that if one of the indicators is green, the project is recoverable. If one of the indicators is yellow and the other is red, negotiation must be considered (recovery miracles do not often happen). If both indicators are red and the project is far enough along for everyone to know red means failure is imminent, there is no alternative—cost and schedule must be renegotiated, or the project must be willing to absorb the financial loss and endure the humiliation of a major schedule slippage. Under these conditions, managers and employees are at risk to be replaced.

A viable action under project manager control is to realign employees to increase their efficiency; however, realignment requires in-depth understanding of the strengths and weak-

Table 1. Recovery strategies.

CR vs. CPI^{-1}	SR vs. SPI^{-1}	Action
Green	Green	Reward employees.
Green	Yellow	Increase OT.
Green	Red	Increase OT or people.
Yellow	Green	Decrease OT.
Yellow	Yellow	Review and adjust assignments.
Yellow	Red	Adjust assignments; consider negotiation (schedule).
Red	Green	Decrease OT or people.
Red	Yellow	Adjust assignments; consider negotiation (funding).
Red	Red	Negotiation (funding, schedule, requirements); fire manager.

nesses of the staff and the roles the project requires. To incorrectly match staff to new roles can seriously impact performance efficiency. The seriousness of the staff deficiencies and the length of time remaining on the project are to be considered in taking employee realignment actions.

Calculations

Two of the more manageable strategies under the sole control of the project manager are varying overtime and number of employees, for which a few helpful formulas are given in the following section. The equations are presented first for schedule recovery, then cost recovery. Bear in mind that reserve funding is used for schedule recovery; people and overtime are increased. For cost recovery, the opposite must occur; people and overtime are decreased at the expense of schedule reserve. It also is important to remember that the formulas are constructed to resolve the predicted schedule or cost overrun by adjusting either staffing or overtime, not both. In other words, the results of the computations can be used to establish the bounds for the management action.

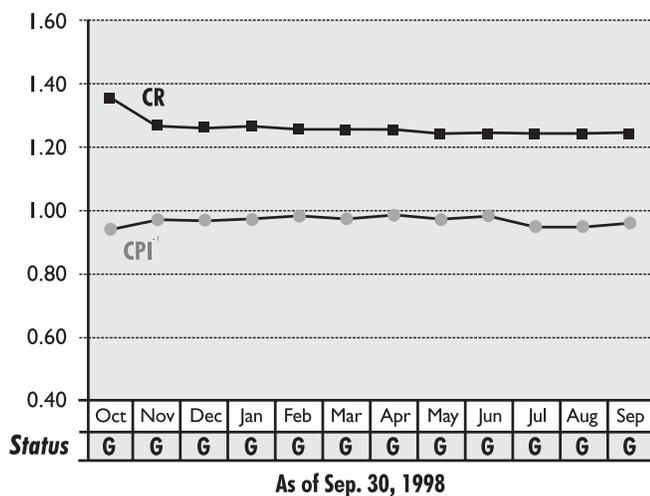
For Schedule Recovery

To determine the average number of employees needed for the remainder of the project, calculate

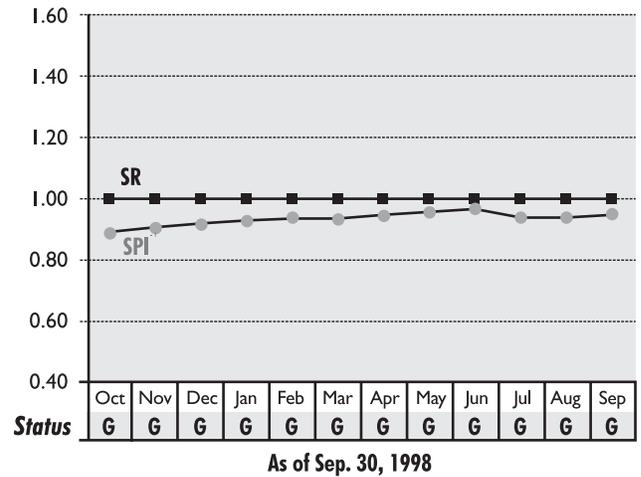
$$E_{SR} = [BAC - BCWP \text{ (cumulative)}] / [CAR \cdot \text{project time remaining (years)}], \text{ where CAR (Cost Accrual Rate) = total average cost per person / year. (The term [BAC - BCWP (cumulative)] represents the project's remaining schedule in dollars.)}$$

The number computed should be larger than the initial average staffing number. The difference in the two numbers provides information regarding the adjustments needed in the project's man-loading profile. If TFA is used instead of BAC, the project can be expected to use all the funding reserve.

Figure 5. Prototype project: cost ratio vs. CPI⁻¹.



Green: Project can be completed within planned cost and may have MR remaining. (CPI⁻¹ ≤ 1.0 and ≤ CR)
 Yellow: Project can be completed within funding available. (CPI⁻¹ > 1.0 and ≤ CR)
 Red: Project cannot be completed within funding if present conditions continue. (CPI⁻¹ > CR)



Green: Project can be completed within planned time. (SPI ≤ 1.0)
 Yellow: Project can be completed within negotiated time. (SPI > 1.0 and ≤ SR)
 Red: Project cannot be completed within negotiated time if present conditions continue. (SPI > SR)

Figure 6. Prototype project: schedule ratio vs. SPI⁻¹.

To determine the overtime (OT) needed, calculate TCSI⁻¹ to determine the ratio of the actual to the planned schedule remaining—the ratio will be larger than one when the project is behind schedule. The computed value of TCSI⁻¹ is then used in the calculation of the OT rate required for the remainder of the project. The elevated OT rate is computed using the following equation.

$$OT_{SR} = (TCSI^{-1}) \cdot (1 + OT_p) - 1, \text{ where } OT_p \text{ is the planned OT rate.}$$

The expectation is that by working at this rate, employees will complete the project on the planned date. If the OT rate exceeds what is considered a “burn out” threshold, an increase in staffing should be considered. If TFA is substituted for BAC, the OT rate required will be less; however, all schedule reserve is expected to be used.

For Cost Recovery

To determine the average number of employees needed for the remainder of the project, calculate

$$E_{CR} = [BAC - ACWP \text{ (cumulative)}] / [CAR \cdot \text{Project time remaining (years)}], \text{ where CAR is the same as for the schedule calculation. (The term [BAC - ACWP (cumulative)] represents the remaining project funds.)}$$

The number computed should be smaller than the initial average staffing number. Similar to schedule recovery, the difference in the two numbers provides useful information concerning the man-loading change needed. If TFA is substituted for BAC, the project can be expected to use all the funding reserve.

The overtime calculation for cost recovery is very similar to the calculation presented previously for schedule recovery. First, calculate TCPI⁻¹ to determine the ratio of the actual to the planned funding remaining—the ratio will be smaller

than one when earned-value efficiency is poor. Analogous to schedule recovery, the value of TCPI⁻¹ is used in the computation of the OT rate for cost recovery required for the remainder of the project. The adjusted OT rate is calculated using the following equation.

$$OT_{CR} = (TCPI^{-1}) \cdot (1 + OT_p) - 1$$

The expectation is that by working at this reduced OT rate, employees will complete the project at the planned cost. If the OT calculation produces a negative number, the project *must* reduce its staffing. If TFA is substituted for BAC in the calculation, a smaller decrease in OT rate will result so as not to exceed the available funding reserve.

Project Application

Over the last year, we have been prototyping these management tools and ideas in a large development project. As can be seen in Figures 5 and 6, not much information about the usefulness of the tools can be stated; the project has performed too well. To date, no cost or schedule recovery has been required. However, a few observations can be made. Before the tools were developed, the only reserve component considered in project planning was funding. Figure 6 illustrates this point; the prototyping project has a schedule ratio of 1, thereby indicating the absence of schedule reserve. Because they recognize the value and reduced risk of having two dimensions of MR, our managers now pay much more attention to the schedule compo-

nent. The new projects are being planned with consideration for schedule reserve.

Other Thoughts

In considering the application of these tools, you should recognize that considerable discretion is required. If applied in too rote a manner, especially early in a project, there is risk of tampering, e.g., overcorrection. Generally speaking, if yellow and sometimes even red indications occur early in the project, it is wise to merely look into the problem and wait for the next review before taking action.

Summary

The concepts presented are extensions of C/SCSC and are targeted to the effective use of MR. The tools presented provide simple visual aids to assess project health, which, in turn, leads to suggested management actions. Calculation formulas are also provided to further refine the recommended management action. This set of management tools should be easily applied by anyone who uses C/SCSC for software project management.

The prototyping of the tools performed to date does not provide sufficient information to show their usefulness. Even so, because we believe that the indicators, prescribed management actions, and formulas are conceptually sound, we are proceeding with their application to other projects. By expanding the application of the MR management technique this year, we

expect to broaden our perspective by gaining additional inputs from several managers. ♦

Reference

1. Fleming, Quentin W., *Cost/Schedule Control Systems Criteria, The Management Guide to C/SCSC*, Probus, Chicago, 1988.

About the Author



Walter H. Lipke is the deputy chief of the Software Division at the Oklahoma City Air Logistics Center. The division comprises approximately 600

employees, most of whom are electronics engineers. He has 30 years experience in the development, maintenance, and management of TPS. In 1993, under his direction, the TPS and industrial automation functions of the division became the first Air Force software activity to achieve Software Engineering Institute Capability Maturity Model CMM Level 2. Likewise, in 1996, these functions became the first software activity in federal service to achieve SEI CMM Level 4 distinction. Recently, under his direction, the TPS and IA software functions achieved ISO 9001 and TickIT registration. He is a professional engineer with a master's degree in physics.

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