Earned Schedule: Application of the To Complete Schedule Performance Index

Walt Lipke
Creator of Earned Schedule

Abstract

Earned Schedule (ES) is an extension to Earned Value Management (EVM). The project management practice has recently been included in PMI documents (PMBOK, EVM and Scheduling Practice Standards), and the ISO EVM standard. ES has facilitated the advancement of EVM in the analysis and control of project schedule performance.

A few years ago, a theoretical study was made of the To Complete Performance Index (TCPI) of EVM. The study concluded that when the TCPI value of 1.10 is exceeded the project is out of control and recovery is very unlikely. Recent analysis using real data has shown that the value 1.10 for TCPI and the To Complete Schedule Performance Index (TSPI) from Earned Schedule is a definitive and reliable performance threshold. This paper describes the use of EVM and ES project performance measures with the established threshold to compute the probability of cost and schedule recovery. Utilizing the computed probability, a schedule performance improvement strategy is discussed for achieving project recovery. The application of the recovery probability and strategy is shown to enhance the likelihood for having a successful project.

Introduction

In the application of Earned Value Management (EVM), the To Complete Performance Index (TCPI) is an important cost performance indicator for project managers (PM) [Fleming, et al, 2009]. What does TCPI tell us? The index value describes the cost performance efficiency required for the remainder of the project to achieve the desired final cost. The value of TCPI can have a very powerful influence on how a PM views the need or urgency for intervention and management action.

The indicator is defined as the work remaining to be accomplished divided by the amount of unspent funding [Project Management Institute, 2011]. The indicator is incredibly useful in that it can be evaluated using cost values different from the Budget at Completion. For simplicity in defining the mathematical formula, this “different” cost is termed the total cost desired (TC). Thus, the index formula is defined as follows:

$$TCPI = (BAC – EV) / (TC – AC)$$

where BAC = Budget at Completion
EV = Earned Value
TC = Total Cost
AC = Actual Cost

Historically, the TCPI value of 1.10 is regarded as a threshold to avoid exceeding if at all possible. Although empirical evidence has not been established, it is believed to be the point at which project performance is out of control; i.e., the probability of recovering to the desired total cost is extremely low.

With the development of Earned Schedule (ES), a comparable indicator has been created for schedule performance management, the To Complete Schedule Performance Index (TSPI). The index value yields the schedule performance efficiency required for the remainder of the project to achieve the desired project duration. The TSPI indicator is defined in the time domain, similarly to TCPI. TSPI is equal to the portion of the planned duration remaining completion divided by the time duration available [PMI, 2011]:

$$TSPI = (PD – ES) / (TD – AT)$$

where PD = Planned Duration
ES = Earned Schedule
TD = Total Duration
AT = Actual Time Duration

Applying similar logic as that used for TCPI, the threshold value of 1.10 is the point at which, when exceeded, achieving the desired project duration (TD) becomes virtually impossible.

Previous Research

The TCPI has been examined in a theoretical sense as to its behavior when the value approaches and then exceeds the value of 1.10 [Lipke, 2009 and 2020]. Figure 1 provides a graphical illustration. As the project progresses to completion, with the Cost Performance Index (CPI) constant at the value of 0.85, TCPI begins to increase gradually until its value is 1.10. From that point, TCPI is observed to become markedly larger for small increases in project fraction complete .

The rate of increase (RI) of TCPI with respect to fraction complete was subsequently evaluated for this example using calculus. The RI was evaluated when TCPI = 1.10 and observed to be a moderate value (1.131). Then RI was computed at a fraction complete greater by only 3.6 percent. The RI was alarmingly larger (1.614). The calculations were then repeated, increasing fraction complete by another five percent; RI became much larger (3.032). Certainly, the probability of successfully achieving the desired project cost becomes extremely low when the cost efficiency required is 1.259 and is increasing at the rate of 300 percent.

The conclusion from the research analysis was "…the TCPI value of 1.10 is a reasonable criterion for determining when a project is not recoverable (to its desired cost) and is 'out of control'" [Lipke, 2009]. Because the formulation and behavior of TSPI is analogous to TCPI, it was likewise concluded that exceeding the TSPI value of 1.10 indicates the project most likely cannot achieve its desired duration.

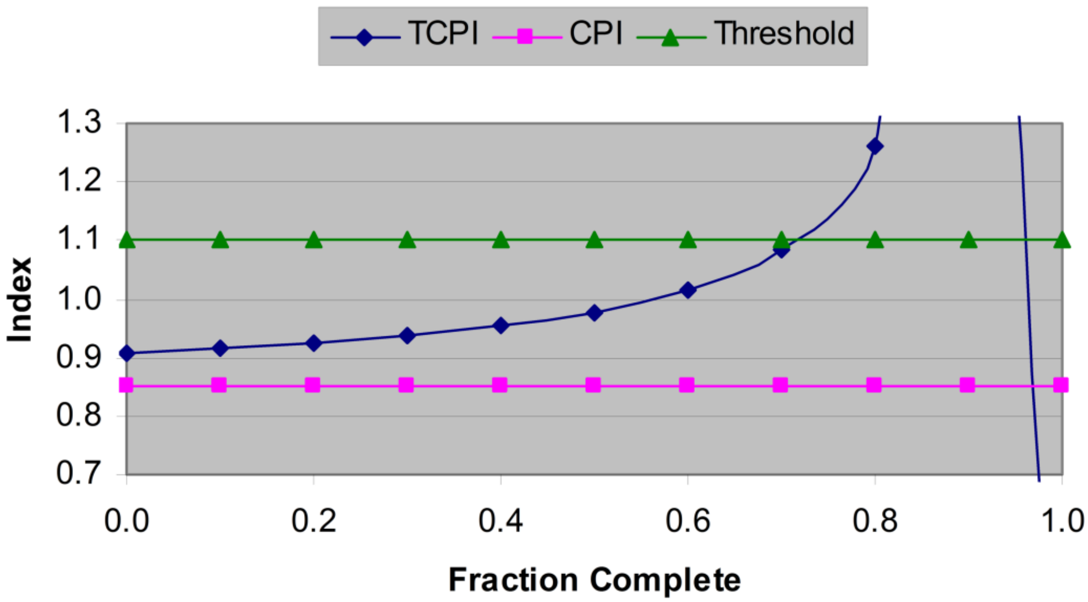

Figure 1. Behavior of the To Complete Performance Index

Beyond establishing the value of 1.10 as a reasonable threshold for TCPI and TSPI, this research described how the To Complete indexes could be used to determine the period of opportunity for project recovery. As an example, let us assume we are managing the project whose performance is portrayed in figure 1. At 30 percent complete, TCPI equals 0.937 and does not cause management alarm. Yet, from the low value of CPI, we know if the poor cost efficiency continues TCPI is likely to increase and approach the threshold. Using a derived expression, the TCPI formula can be applied to determine the percent complete when the threshold value is reached, assuming no management intervention. [1] For our example, this occurs at 71 percent complete. Thus, with very little effort, it has been determined that we have the next 41 percent of project achievement to effect corrective actions and render a successful outcome, i.e., the period of opportunity.

[1] By dividing the numerator and denominator by BAC, TCPI can be expressed in terms of fraction complete and CPI [Lipke, 2009].

Evaluation Methodology

Data Description. EVM data from twenty five projects was used to evaluate the validity of the TCPI and TSPI threshold value, 1.10. The project data comes from three sources and is highly varied: four projects are information technology; twelve come from high technology product development; nine are construction type projects. The projects range in duration from a few months to several years. There is no indication in the data of reserves for cost or duration. A significant data characteristic is the projects have not undergone re-planning. The use of projects void of re-planning enables a cleaner, less encumbered evaluation of the study results, by not having to account for the disturbance.

TCPI and TSPI Values for Evaluation. For each of the 25 projects, TCPI and TSPI are calculated at each of their respective status points. To evaluate the effect of reserves, the calculations were repeated for reserve amounts of 5, 10, and 15 percent. [2] The project cost and duration outcomes for each reserve scenario are classified as one of three possibilities: over, at, or under in relation to their respective allocations. These outcomes are then used to select TCPI and TSPI values needed for testing by segregating performance into two areas, those that satisfy the completion requirements and those that do not:

1. For projects that do not complete within their cost or duration (to include reserves), the first TCPI or TSPI value exceeding 1.10 was recorded. The condition to identify the "first value" is the first after the project has completed, at minimum, 20 percent of the BAC or PD, as appropriate.
2. For those projects completing at, or within, their cost or duration (including reserves), the largest value for TCPI or TSPI was recorded. Just as for the delinquent projects, the values recorded are identified after the project is at least 20 percent complete.

The rationale for the two groupings is readily explainable. If exceeding the value of 1.10 correlates to a delinquent project, then the first instance is sufficient for the analysis. For the non-delinquent projects, the largest value provides information concerning whether projects can be recovered when the threshold is exceeded.

The recorded values of TCPI and TSPI along with their associated cost and duration outcomes for the 25 projects are then examined through statistical hypothesis testing [Crowe, et al, 1960].

Hypothesis Tests. Four hypothesis tests are performed, two each for TCPI and TSPI. The tests are performed for each of the four reserve percentages (0, 5, 10, 15). Thus, each index is evaluated from the results of eight tests. The hypothesis test method used is the Sign Test

[2] Reserve amounts are computed in relation to BAC for cost and PD for duration.

[NIST, 2022]. The test is made for the null hypothesis, identified as Ho. When there is insufficient statistical evidence to support Ho, the test result is the alternate hypothesis, Ha.

The four hypothesis tests used to evaluate the threshold are defined, as follows:

1. For projects having TCPI ≤ 1.10, identify those over budget
   Ho: Completion within budget is unlikely
   Ha: Completion within budget is likely

2. For projects having TCPI > 1.10, identify those on or under budget
   Ho: Cost recovery is possible
   Ha: Cost recovery is unlikely

3. For projects having TSPI ≤ 1.10, identify those completing late
   Ho: On-time/early delivery is unlikely
   Ha: On-time/early delivery is likely

4. For projects having TSPI > 1.10, identify those completing on-time or early
   Ho: Duration recovery is possible
   Ha: Duration recovery is unlikely

For each of the four tests, the test statistic is computed and compared to a significance level (α) equal to 0.05.[3] When the test statistic value is less than or equal to 0.05, there is enough evidence to reject the null hypothesis. The test statistic for the Sign Test is computed using the binomial distribution. The computed value is the probability of a specific number of successes occurring from a number of trials, each having the probability of success equal to 0.5. The number of trials is determined from applying the index condition stated in the test definition; while from the projects identified, the successes counted are those having the stated performance outcome.

Analysis and Test Results

The effect of reserves is readily seen in the project outcomes. As reserves are increased, the number of projects meeting or exceeding performance expectations increases. Table 1 is a compilation of the impact of the various reserve amounts.

Of course having reserves increases the likelihood of successful project completion. In addition to this expectation, the table illustrates the impact of reserves on the calculation of the test statistic for hypothesis test evaluation. For example, consider hypothesis test 1. Only those projects meeting the requirement TCPI ≤ 1.10 are subject to the testing (the number of trials).

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[3] A complete description of the terms "test statistic" and "significance level" is available in mathematics books of statistics [Crowe, et al, 1960].

Of those the number completed exceeding the desired cost are counted and used in the calculation (the number of successes). Thus, for the example, it is apparent that the numbers used in the test statistic calculation are less than the total number of projects. The point to be understood from the foregoing discussion is that it is possible the selection process may cause sample size to be very small. When this occurs, the hypothesis test result becomes questionable.

	Cost Outcomes			Schedule Outcomes		
Reserve	**Under**	**At Budget**	**Over**	**Early**	**On Time**	**Late**
0%	6	0	19	3	4	18
5%	9	2*	14	9	2	14
10%	11	0	14	9	3	13
15%	13	0	12	14	1	10

* Projects for which final cost was very close to budget, one within 0.8% and the other 0.3%.

Table 1. Cost and Schedule Outcomes

An example of hypothesis tests 3 and 4 is shown in Table 2. Columns 3 and 6 have the heading "E, O, L" and identify the outcome for each project. The legend at the bottom of the table defines the letters: E = Early, O = On-Time, L = Late. The TSPI threshold evaluation is for the scenario with reserve equal to 10 percent. Columns 2, 3, and 4 depict test 3, while columns 5, 6, and 7 are for test 4. Identical data is used for both tests; thus column 2 is the same as column 5, and column 6 replicates column 3. The difference in the two tests is the evaluation made in the two Sign columns.

For test 3 the projects having TSPI $\leq$ 1.10 are evaluated:

"+" is assigned when "L" is observed

"-" is assigned when "O" or "E" is observed

"0" is assigned for those projects not satisfying TSPI $\leq$ 1.10

Test 4 evaluates those projects having TSPI > 1.10:

"+" is assigned when "O" or "E" is observed

"-" is assigned when "L" is observed

"0" is assigned for those projects not satisfying TSPI > 1.10

From the assigned symbols (+, -, 0) the test statistic may be calculated:

R+ = the number of projects with "+"

N = total number of projects

n = number of projects with "0"

S+ = test statistic value

α = level of significance

Projects	TSPI	E, O, L	Sign	TSPI	E, O, L	Sign
1	1.250	L	0	1.250	L	-
2	1.118	L	0	1.118	L	-
3	1.601	L	0	1.601	L	-
4	1.134	O	0	1.134	O	+
5	0.905	E	-	0.905	E	0
6	1.118	L	0	1.118	L	-
7	1.200	L	0	1.200	L	-
8	1.006	E	-	1.006	E	0
9	1.156	L	0	1.156	L	-
10	1.129	L	0	1.129	L	-
11	1.115	L	0	1.115	L	-
12	1.115	E	0	1.115	E	+
13	0.928	E	-	0.928	E	0
14	0.782	E	-	0.782	E	0
15	0.893	E	-	0.893	E	0
16	0.833	E	-	0.833	E	0
17	1.066	E	-	1.066	E	0
18	1.137	L	0	1.137	L	-
19	1.000	O	-	1.000	O	0
20	1.587	L	0	1.587	L	-
21	0.947	E	-	0.947	E	0
22	2.000	L	0	2.000	L	-
23	1.120	O	0	1.120	O	+
24	1.439	L	0	1.439	L	-
25	1.169	L	0	1.169	L	-
Calc Values						
R+	Selects the projects having TSPI ≤ 1.10 identifying those that completed Late		0	Selects the projects having TSPI > 1.10 identifying those that completed On-Time or Early		3
N			25			25
n			16			9
S+			0.00195			0.01064
α			0.05			0.05
Test Result						
Ho or Ha	Ho: On-time delivery is unlikely		Ha	Ho: Recovery is possible		Ha
	Ha: On-time delivery is likely			Ha: Recovery is unlikely		
Legend: E = Early O = On Time L = Late						

Table 2. Example of Hypothesis Test

As shown in table 2, the alternate hypothesis, Ha, is the test result for both test 3 and test 4. The test statistic value, S+, is less than the value for α (0.05): test 3, S+ = 0.00195 < 0.05; test 4, S+ = 0.01064 < 0.05. For this circumstance, S+ less than α, there is enough evidence to reject the null hypothesis. Thus, for test 3, Ha indicates on-time delivery is likely when TSPI ≤ 1.10. The Ha result for test 4 indicates that recovery to the desired project duration is unlikely when TSPI > 1.10.

The hypothesis test results for the four reserve scenarios are compiled and provided in tables 3 and 4. Table 3 contains the eight results from testing the TCPI threshold. The result from each of the TCPI hypothesis tests (1 and 2), regardless of scenario, is Ha:

Test 1) When TCPI $\leq$ 1.10 completion within the desired budget is likely

Test 2) When TCPI > 1.10 recovery to the desired budget is unlikely

Reserve	TCPI $\leq$ 1.10	At/Under Budget	Test Statistic	α = 0.05 Ho or Ha	TCPI > 1.10	Over Budget	Test Statistic	α = 0.05 Ho or Ha
0%	6	6	0.01563	Ha	19	19	0.00000	Ha
5%	10	10	0.00098	Ha	15	14	0.00049	Ha
10%	12	11	0.00317	Ha	13	13	0.00012	Ha
15%	14	13	0.00092	Ha	11	11	0.00049	Ha

Table 3. TCPI Threshold Hypothesis Test Results

The compiled results for the hypothesis tests (3 and 4) of the TSPI threshold are provided in table 4. As shown, each test result is Ha, with one exception. The one exception is the hypothesis test result for the projects with TSPI $\leq$ 1.10 and the scenario of zero reserves. For this test, the sample size was only three projects. For those three projects, none finished late; that is, all completed on-time or early. Because the sample size is so small, the test statistic (0.12500) is not truly representative of threshold performance. The observed outcomes from the three project sample indicate that when TSPI is maintained $\leq$ 1.10, on-time project delivery is an expectation; i.e., in essence the Ha result. Thus, the overall hypothesis test results for TSPI mirrors those for TCPI:

Test 3) When TSPI $\leq$ 1.10 on-time/early delivery is likely

Test 4) When TSPI > 1.10 recovery to the desired duration is unlikely

Reserve	TSPI $\leq$ 1.10	On Time / Early	Test Statistic	α = 0.05 Ho or Ha	TSPI > 1.10	Late	Test Statistic	α = 0.05 Ho or Ha
0%	3	3	0.12500	Ho	22	18	0.00217	Ha
5%	8	8	0.00391	Ha	17	14	0.00636	Ha
10%	9	9	0.00195	Ha	16	13	0.01064	Ha
15%	13	13	0.00012	Ha	12	10	0.01929	Ha

Table 4. TSPI Threshold Hypothesis Test Results

With the establishment of the threshold value, it becomes possible to compute the probability of project recovery (PRcv) for both, cost and schedule. In turn, having knowledge of the probability is envisioned to be useful to project management. For example, when final cost is forecast to exceed the total budget, yet TCPI is less than 1.10, indicating there may be opportunity for recovery, the project manager (PM) has a decision to make: Should he/she take action to effect recovery or not? The value of PRcv is a needed component in the PM's decision process.

Probability Theory

The probability that the mean (M) of a number of observations (O), having a normal distribution, is larger than a selected value (V) is determined from the following equations [Crowe et al, 1960]:

$$X = (M - V) / (\sigma/\sqrt{n})$$
$$\sigma = \sqrt{(\Sigma(O_i - M)^2 / (n - 1))}$$

where
X = the statistically normalized difference of M minus V
σ = the estimated standard deviation of the observed measures
n = the number of measures
O_i = one of the observations

The computed value of X is converted to probability using either the normal or t-distribution. The t-distribution is applied when the number of observations is less than 30.

When the observations are from a finite data set, the denominator of the equation for X is multiplied by the adjustment factor $\sqrt{((N - n) / (N - 1))}$, where N is the total number of observations and n is the number in the sample [Crowe et al, 1960]. Because projects are finite, the adjustment factor is pertinent to the calculation of PRcv.

Probability of Recovery

To compute the probability for when the value of TCPI or TSPI is, say, less than or equal to the threshold value (1.10) two characteristics must be determined:

1) *Are the values from the periodic measures of the index distributed normally?*
2) *Is the number of index measures finite?*

For TCPI and TSPI, the number of status values is limited by project completion, and therefore finite. However, the indicators behave oddly, especially for poor performing projects. For projects performing well, the indicators monotonically decrease in value, reaching zero at completion. For poor performing projects, the indicator values increase past the threshold, have a divide by zero condition, then turn negative and finally return to zero at completion. From this odd characteristic behavior along with the lack of meaning for periodic values of the indicators, it is logically inferred that their respective statistical distributions are indeterminate. Thus, the To Complete indexes do not satisfy the requirements and we have a conundrum:

The probability of project recovery is dependent upon the TCPI and TSPI values relative to the threshold, 1.10. How can the probability be computed without discerning their statistical characteristics?

Resolving the Dilemma. Let's begin by viewing TCPI and TSPI in a different form. For TCPI, the changed form is created by dividing the numerator and denominator of the defining equation by BAC. And, for TSPI, the numerator and denominator are divided by PD. The transformed equations are shown below:

$$TCPI = (1 - EV\%) / (CR - EV\%/CPI)$$
$$TSPI = (1 - ES\%) / (SR - ES\%/SPI(t))$$

where

EV% = EV/BAC	ES% = ES/PD
CR = TC/BAC	SR = TD/PD
CPI = EV/AC	SPI(t) = ES/AT

The abbreviations, CPI and SPI(t), are the Cost Performance Index and the Schedule Performance Index (time), respectively.

Upon setting TCPI and TSPI to the threshold value, 1.10, the above transformed equations are solved for CPI and SPI(t), respectively. The resultant solutions follow:

$$CPI_T = 1.10\ EV\% / (1.10\ CR - 1 + EV\%)$$
$$SPI(t)_T = 1.10\ ES\% / (1.10\ SR - 1 + ES\%)$$

The subscript T denotes that these formulas provide the threshold values for which the performance values of CPI and SPI(t) are to be compared. When the performance value is less than the comparable threshold value, the To Complete index threshold has been breached.

To enhance understanding, graphs of $SPI(t)_T$ are shown in figure 2. Three plots are depicted to illustrate the effect of various values of SR; the value of SR is in parenthesis for each of the legend identifiers. For the value 1.0, TD equals PD, indicating there is no schedule reserve; for the value 1.1, 10 percent of TD is reserve and for 1.2, 20 percent is reserve. From analysis of the three graphs, we observe that as SR increases the $SPI(t)_T$ value decreases for the same value of fraction complete (ES%). Thus, it is easily deduced that as reserves increase, the performance values of SPI(t) can decrease and not cause TSPI to exceed 1.10. The above description may be applied, analogously, to CPI_T, CR, CPI, and TCPI for cost performance analysis.

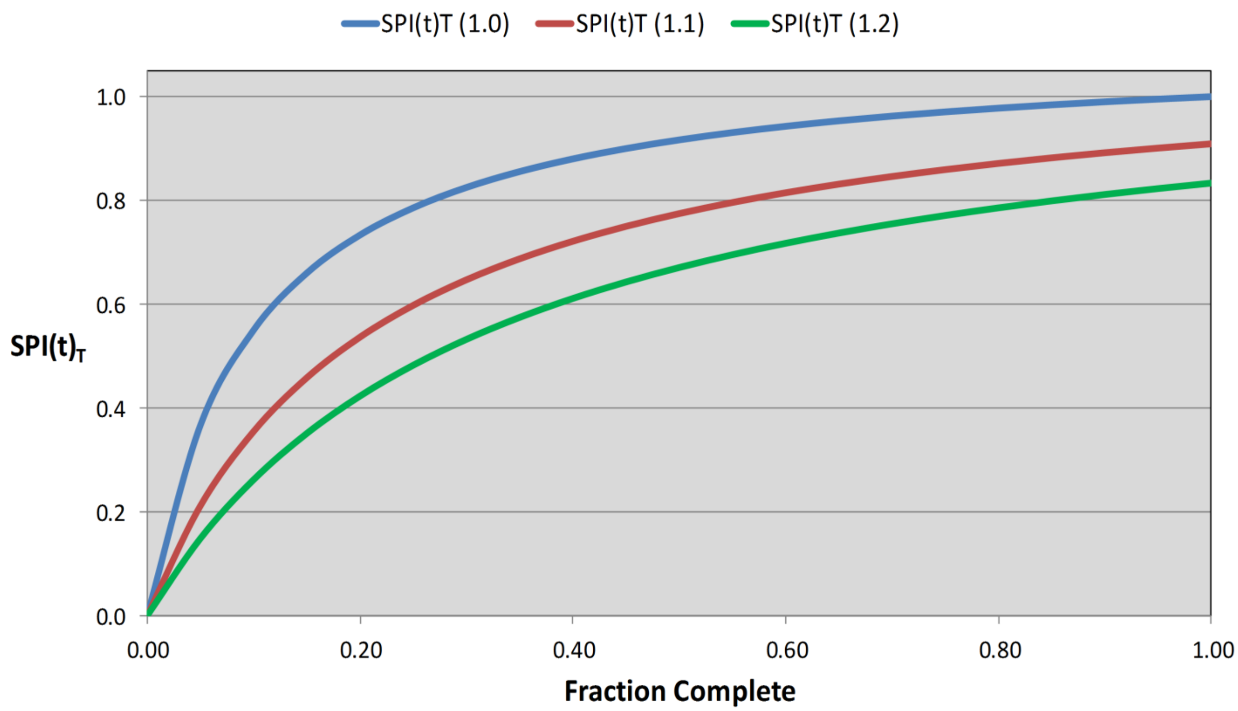

Figure 2. $SPI(t)_T$ Behavior

Application of Statistics. The periodic values of CPI and SPI(t) from real projects have been tested and determined to be lognormally distributed [Lipke, 2020]. Furthermore, it can be shown mathematically that the mean of the lognormal distribution is equal to the log of the cumulative value of the index. To clarify, using the schedule indexes: $\ln SPI(t)_C = \Sigma(\ln SPI(t)_i)/n$, where the subscripts C and i denote cumulative and periodic, respectively, and ln is the logarithm function.

By transforming the threshold for TCPI and TSPI to CPI_T and $SPI(t)_T$ functions, the statistical characteristics of CPI and SPI(t) can be utilized. Figure 3 illustrates the normal distribution of the periodic values of ln SPI(t), as well as the placement of $\ln SPI(t)_C$ and $\ln SPI(t)_T$. For the pictorial example, the project has an estimated 90 percent probability of recovering to its TD. The probability is determined from the area beneath the normal curve beginning at $\ln SPI(t)_T$ and extending to plus infinity. At 90 percent, the PM has a good opportunity to take positive action and have a successful project.

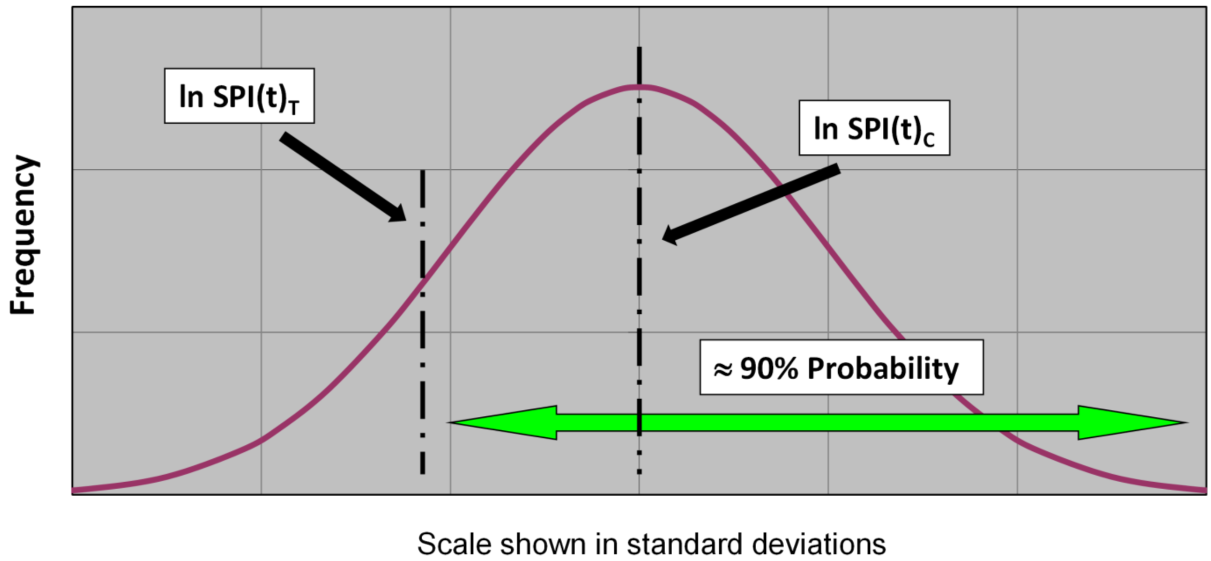

Figure 3. Probability Example

Probability Calculation. To perform the probability of recovery calculation, substitutions for variables, M, V, and O_i, are made in the equations for X and σ described previously in the *Probability Theory* section. Table 5 is a compilation of the cost and schedule substitutions. Included, as well, are the finite data adjustment factors required for projects.

Three graphs of computed results for probability of recovery are portrayed in figure 4. For the calculations, the values for $SPI(t)_C$ and σ are held constant at 0.87 and 0.30, respectively, as ES% increases to 1.0. The value of 0.87 is purposely chosen to demonstrate poor schedule performance, while the σ value is typically observed. Each of the graphs, PRcv(1.0), PRcv(1.1), and PRcv(1.2), is an example of probability behavior over the duration of the project. The number in parenthesis is the value of SR used in the calculations. For instance, 1.0 in the notation, PRcv(1.0), indicates the total duration is equal to PD.

Variable	Cost	Schedule
M	$\ln CPI_C$	$\ln SPI(t)_C$
V	$\ln CPI_T$	$\ln SPI(t)_T$
O_i	$\ln CPI_i$	$\ln SPI(t)_i$
√((N – n) / (N – 1))	√((BAC – EV) / (BAC – EV/n))	√((PD – ES) / (PD – ES/n))

Table 5. Cost and Schedule Substitutions

The figure illustrates the influence of schedule reserve on PRcv. The graph of PRcv(1.0) shows a decreasing probability value until, at approximately 85 percent complete, actual duration has exceeded PD. From that point until completion PRcv equals 0.0; it is impossible to recover. The PRcv(1.1) graph indicates there is good opportunity for recovery until the project has progressed to approximately 70 percent complete. The probability decreases rapidly thereafter until the actual duration exceeds 1.1 PD. For the PRcv(1.2) graph, TD is greater than the actual duration at completion. The probability approaches 1.0 very early and at completion equals 1.0.

The examples and figures throughout the article have been presented in reference to schedule performance. However, the discussion points are equally applicable to cost. In this confined context, cost and schedule analysis are perfectly analogous. The threshold behavior of CPI_T is identical to $SPI(t)_T$ in figure2. As well, the interpretation of figure 3 is unchanged when CPI is substituted for SPI(t). And lastly, the PRcv graphs in figure 4 are identical for cost, when performance and risk reserve mimic the values employed for schedule.

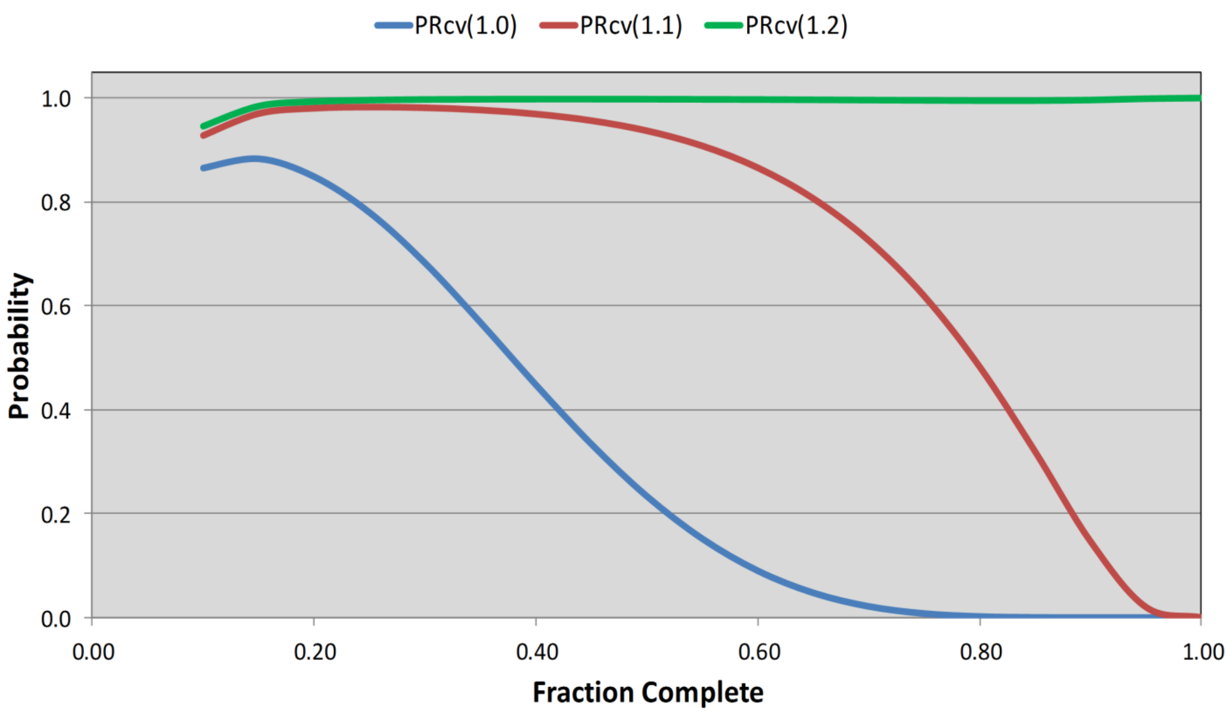

Figure 4. Probability of Recovery

Notional Data Example

A small set of data has been created to demonstrate the management application of PRcv. The data and computed results are consolidated in Table 6. The majority of the headings have been introduced previously; however, four have not: Mo, PV, PO%, and IEAC(t). The abbreviation Mo is month, while the abbreviations PV and IEAC(t) are Planned Value, and Independent Estimate at Completion (time), respectively. The heading PO% is the Period of Opportunity percentage. The value of PO% represents the portion of PD from the present status point until the threshold is exceeded if present SPI(t) continues; i.e., it provides management with information concerning the opportunity to take corrective action.

Mo	PV	EV	ES	SPI(t)	TSPI	PO%	IEAC(t)	PRcv
1	3023	928	0.307	0.307	1.099		26.1	
2	7828	7152	1.859	0.930	1.023	31.3%	8.6	0.574
3	13951	13302	2.894	0.965	1.021	35.1%	8.3	0.591
4	19967	17077	3.520	0.880	1.120	Unlikely	9.1	0.477
5	24286	23061	4.716	0.943	1.095	1.2%	8.5	0.505
6	30989	28681	5.656	0.943	1.172	Unlikely	8.5	0.440
7	36709	32526	6.269	0.896	1.731	Unlikely	8.9	0.219
8	38140	34513	6.616	0.827	#DIV/0!	None	9.7	0.000
9		36709	7.000	0.778	-1.000	None	10.3	0.000
10		38140	8.000	0.800	0.000	None	10.0	0.000

Table 6. Analysis Example

From the PV data, we can see the project has a planned duration of eight months. The effort is considered low risk and has no reserve; i.e., product delivery is to occur upon completion of the 8th month. However, the EV column shows performance lagged expectation with the project completing two months late.

For delivery to occur as planned, SPI(t) must equal 1.000 at project completion, and should be maintained close to that value throughout execution. Correspondingly, the forecast duration shown in column, IEAC(t), needs to hover around 8.0 to have the expectation of delivering on time. As the project progresses, neither SPI(t) nor IEAC(t), provide confidence of project success; SPI(t) is consistently less than 1.000 and IEAC(t) is always greater than 8.0 periods.

Early in the execution, the PM can see that the project is in trouble. However, utilizing only SPI(t) and IEAC(t), there is not enough information to determine if recovery action is possible, or practical. To be possible, the PM needs to know that TSPI has not exceeded the threshold value. To decide whether a recovery action is appropriate and worthwhile, the PM must answer two questions:

1. *Is there opportunity to make necessary performance corrections?*
2. *What is the probability of having a successful recovery?*

The value of PO% answers question 1, while PRcv answers 2.

Although we may be able to answer the above questions, there is another aspect to consider. Some amount of execution is needed to have confidence in the management information. Generally, to achieve a level of performance data sufficiency, the execution required for EVM analysis is the initial 15 or 20 percent of the effort. Choosing 15 percent, the table values for analysis of the hypothetical project are considered when ES is equal to or greater than 1.2 months. Thus for the first month, the values shown may be ignored; ES is less than 0.4 months. For month 2, ES equals 1.859 making values for months 2 through 10 usable for analysis.

Examining the values in the table for months 2 and 3, we can see that the PM has information for SPI(t) and IEAC(t), indicating poor performance. Also, we observe that TSPI has not exceeded the threshold and recovery is possible. With PO% greater than 30 percent and PRcv close to 60 percent, the PM can feel reasonably confident that recovery intervention is appropriate.

Of course during execution of months 2 and 3, our PM does not know that if he/she chooses not act, TSPI will exceed the threshold in period 4 and project delivery is not likely to occur as planned. The PM, recognizing poor performance, must balance the inefficiency caused by intervention with the possibility that improvement can be made. Inherently, the PM reacts either from intuition and experience, or from external pressure. By utilizing PRcv in the analysis process, improvement can be expected; it becomes possible to make decisions earlier with greater confidence. And, by taking reasoned and appropriate action, TSPI just might not exceed the threshold in period 4 and the project achieves success with the product delivered on time.

Summary

Theoretical and recent empirical research has shown that the value of 1.10 is very likely a valid threshold for both, TCPI and TSPI. When the To Complete index exceeds 1.10, the project most likely will not meet its commitment, i.e., target cost or delivery date.

Having evidence the threshold is valid it was thought the probability of recovery could be computed. From inspection, however, the characteristic behavior of the To Complete indexes was deduced to be erratic. Understanding the TCPI and TSPI cannot be directly used, an alternative approach was created. The method incorporates the 1.10 value and the established lognormal characteristics of CPI and SPI(t). Conceptually, although there is complexity, the method for computing PRcv is essentially identical for cost and schedule.

An example analysis was made using notional data. The analysis illustrates how PRcv in conjunction with TSPI and PO%, along with schedule performance efficiency and forecasting must necessarily be used together for making the decision to take recovery action.

The probability of recovery is foreseen to be a very useful aid in determining when project management intervention can be beneficial.

Calculation Aid

To promote uptake and use of PRcv, the Probability of Recovery Calculator for both cost and schedule is freely downloadable from the Earned Schedule website, (www.earnedschedule.com). The calculator is an easy to use Excel spreadsheet, requiring only EVM and ES data normally available.

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About the Author:

Walt Lipke retired from federal service with over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics. As a manager, a career highlight was his organization's winning of the Software Engineering Institute / Institute of Electrical and Electronics Engineers award for Software Process Achievement. 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 creator of Earned Schedule (ES). Mr. Lipke has published over ninety articles on the method, as well as two books, Earned Schedule and Earned Schedule Plus. Additionally, he has presented research on ES and its schedule performance analysis methods at several conferences in the United States, and internationally.

For his contribution to project control, the practice of EVM, and the creation of ES, Mr. Lipke has received several awards: 2007 Project Management Institute Metrics Specific Interest Group Scholar Award; 2007 Project Management Institute Eric Jenett Award for Project Management Excellence; 2013 Earned Value Management Europe Award; 2014 College of Performance Management Driessnack Distinguished Service Award; In 2017, the Australian Project Governance and Control Symposium honored Mr. Lipke by establishing the annual Walt

Lipke Project Governance and Control Excellence Award. The award is made for excellence in research, expanding knowledge of the management and governance of projects, programs, and portfolios in Australasia.