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The Probability of Project Recovery

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Abstract

A few years ago, a theoretical study was made of the To Complete Performance Index of Earned Value Management. The study concluded that when the value of 1.10 is exceeded recovery of the project is very unlikely. Recent analysis using real data has shown that the value 1.10 for the To Complete indexes from Earned Value Management and Earned Schedule is a reliable threshold, adding credence to the conclusion from the theory assessment. This paper describes how to use project performance measures with the established threshold to compute the probability of schedule and cost recovery. Knowing the probability provides additional and beneficial information, thereby enhancing the decision-making capability of project managers.

Introduction

Recent research, using real data from 25 projects, indicates that the value 1.10 is a reliable threshold for the To Complete Performance Index (TCPI) and the To Complete Schedule Performance Index (TSPI) [Lipke, 2016]. The research affirmed the conclusion made from a theoretical assessment that when the threshold is exceeded after 20 percent project completion, recovery is very unlikely [Lipke, 2009-1]. As well, it was shown that when the index value is equal to or less than the threshold, a successful project can be expected; i.e., the product is achieved within the total budget and delivery to the customer is made on or before the negotiated completion date.

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.

Succinctly, there is need for knowing and using the PRcv. The remainder of the article is devoted to developing the method of its calculation. To create the foundation for understanding we will begin from a common point with the definitions of the To Complete Indexes, and proceed to an introduction of probability theory.

To Complete Formulas.

The TCPI from Earned Value Management (EVM) describes the cost performance efficiency required for the remainder of the project to achieve the desired final cost [Project Management Institute (PMI), 2011]. The index formula is defined as follows:

TCPI = (BAC – EV) / (TC – AC)

where BAC = Budget at Completion
EV = Earned Value
TC = Total Cost (BAC plus cost risk reserve)
AC = Actual Cost

TSPI is the time-based To Complete indicator, derived from the application of Earned Schedule [Lipke, 2009-2]. The indicator yields the schedule performance efficiency required for the remainder of the project to achieve the desired project duration [PMI, 2011]. The formula for TSPI is shown below:

TSPI = (PD – ES) / (TD – AT)

where PD = Planned Duration
ES = Earned Schedule
TD = Total Duration (PD plus schedule risk reserve)
AT = Actual Time Duration

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 acronyms, CPI and SPI(t), are the Cost Performance Index and the Schedule Performance Index (time), respectively [PMI, 2011].

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 1. 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.

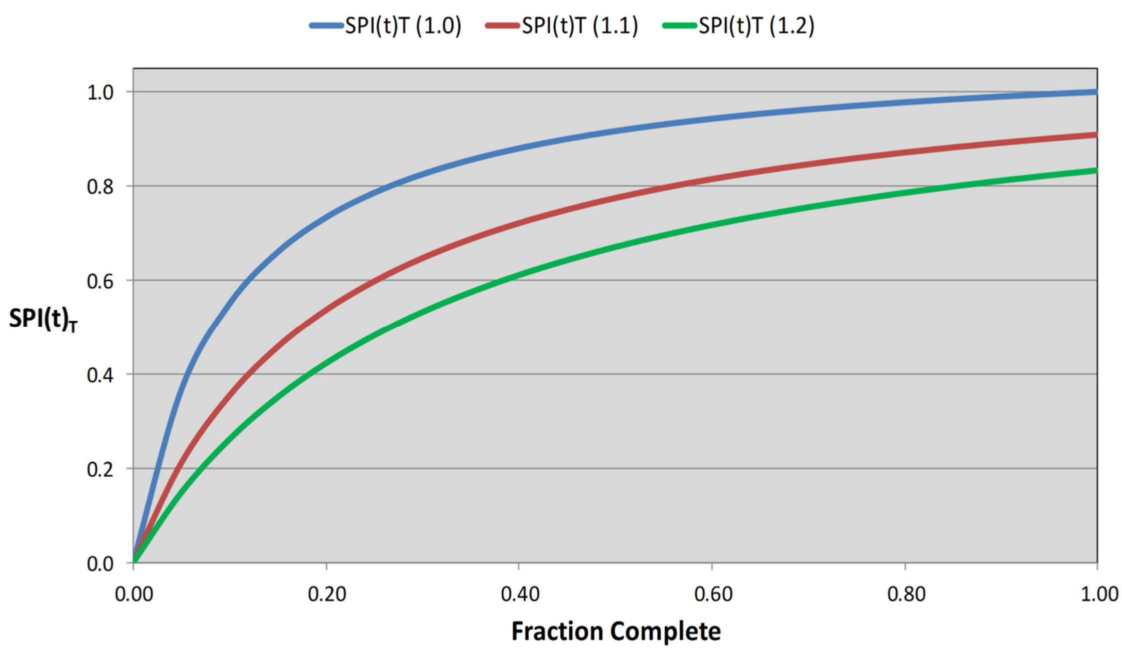

Figure 1. $SPI(t)_T$ Behavior

Application of Statistics.

The periodic values of CPI and SPI(t) from real projects have been tested and determined to be lognormally distributed [Lipke, 2002 and 2012]. 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 2 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.

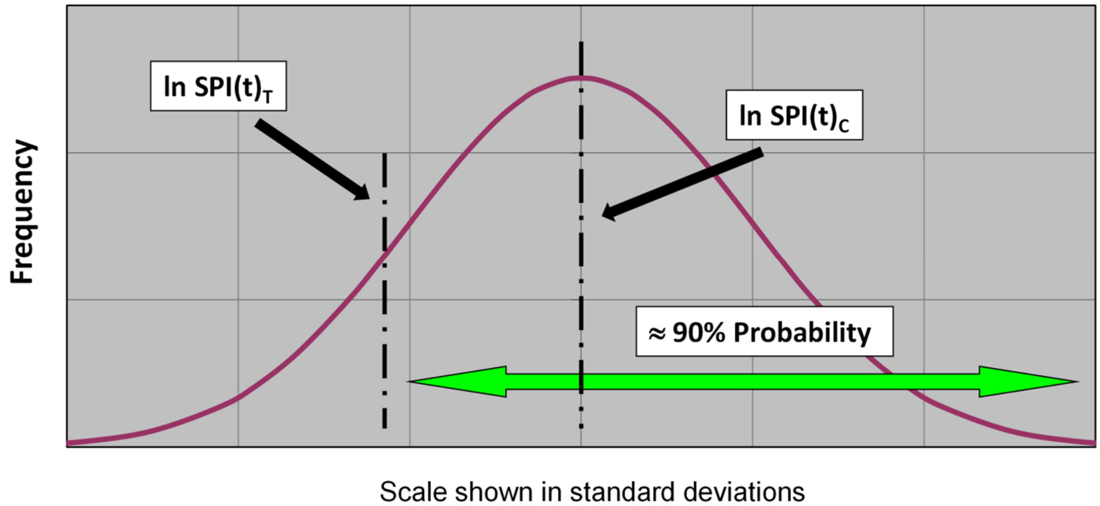

Figure 2. Probability Example

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 1 is a compilation of the cost and schedule substitutions. Included, as well, are the finite data adjustment factors required for projects[1].

Three graphs of computed results for probability of recovery are portrayed in figure 3. 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	$\ln CPI_i$	$\ln SPI(t)_i$
$\sqrt{(N-n)/(N-1)}$	$\sqrt{(BAC-EV)/(BAC-EV/n)}$	$\sqrt{(PD-ES)/(PD-ES/n)}$

Table 1. 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

[1] Explanation of the finite adjustment factors for cost and schedule is available in the reference [Lipke, 2009-2]

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.

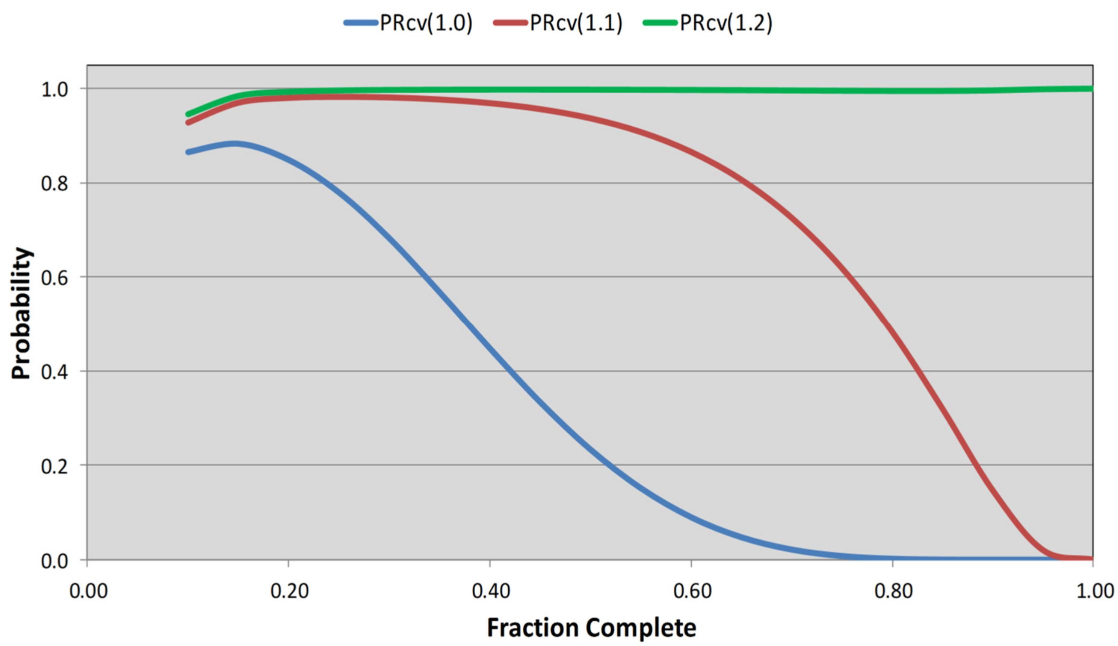

Figure 3. Probability of Recovery

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 figure1. As well, the interpretation of figure 2 is unchanged when CPI is substituted for SPI(t). And lastly, the PRcv graphs in figure 3 are identical for cost, when performance and risk reserve mimic the values employed for schedule.

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 2. 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 [PMI, 2011]. The heading PO% is the Period of Opportunity percentage [Lipke, 2009-1]. 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 2. 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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Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base, where he led the organization to the 1999 SEI/IEEE award for Software Process Achievement. He is the creator of the *Earned Schedule* technique, which extracts schedule information from earned value data.

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- PMI Eric Jenett Award (2007)
- EVM Europe Award (2013)
- CPM Driessnack Award (2014)
- Australian Project Governance and Control Symposium established the annual Walt Lipke Project Governance and Control Excellence Award (2017)
- Albert Nelson Marquis Lifetime Achievement Award (2018)