

# Earned Schedule

## Application of the To Complete Schedule Performance Index

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# Abstract

- A few years ago, a theoretical study was made of the To Complete Performance Index (TCPI) of Earned Value Management. 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 presentation describes the use of Earned Value Management/Earned Schedule 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 enhances the likelihood for having a successful project.



# Objective

- Examine the claim that the value of 1.10 for TCPI and TSPI is a reliable management threshold
- Validate/invalidate the assertion that exceeding the value of 1.10 indicates the project is not recoverable
- Develop and demonstrate the “window of opportunity” and the probability of recovery project management tools



# Overview

- Introduction
- Examination of TCPI & TSPI Behavior
- Empirical Research
- Probability of Recovery
- Project Control
- Summary



# Introduction

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## Review & Application



# Introduction / TCPI & TSPI

- General acceptance – TCPI is an important cost performance indicator
- What is TCPI? ...*the indicator is defined as the work remaining to be accomplished divided by the unexpended portion of available funding*
- Why is TCPI important for PMs? ...*it describes the cost performance efficiency needed for the remainder of the project to achieve the desired final cost*
- The TCPI value has a powerful influence on the need or urgency for intervention and management action.



# Introduction / TCPI & TSPI

- The *To Complete Performance Index* formula is defined as follows:

$$\text{TCPI} = (\text{BAC} - \text{EV}) / (\text{TC} - \text{AC})$$

where BAC = Budget at Completion

EV = Earned Value

TC = Target Cost

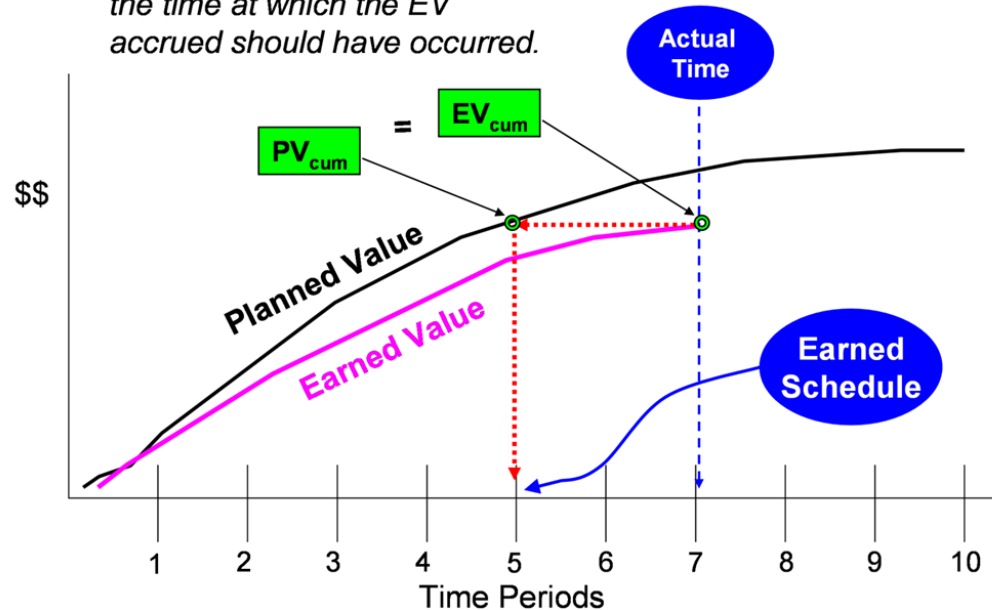
AC = Actual Cost

- Historically,  $\text{TCPI} > 1.10$  has been assumed to be the point at which project cost performance is out of control
- Empirical evidence has not been established to confirm

# Introduction / Earned Schedule



*The ES idea is to determine the time at which the EV accrued should have occurred.*



Time based schedule performance efficiency:  $SPI(t) = ES / AT$





# Introduction / TCPI & TSPI

- With the development of Earned Schedule (ES), the *To Complete Schedule Performance Index* (TSPI) has been created for schedule performance management:

$$\text{TSPI} = (\text{PD} - \text{ES}) / (\text{TD} - \text{AT})$$

where PD = Planned Duration

ES = Earned Schedule

TD = Target Duration

AT = Actual Time Duration

- As for TCPI, the value of 1.10 for TSPI is believed to be the point at which, when exceeded, schedule performance is out of control

# Introduction / Application

- Assuming the value of 1.10 is valid, performance classification is possible

TCPI/TSPI Value	Predicted Outcome
$\leq 1.00$	Achievable
$> 1.00 \leq 1.10$	Recoverable
$> 1.10$	Not Achievable

- As well, contractor EAC can be evaluated ..realistic? ..achievable?



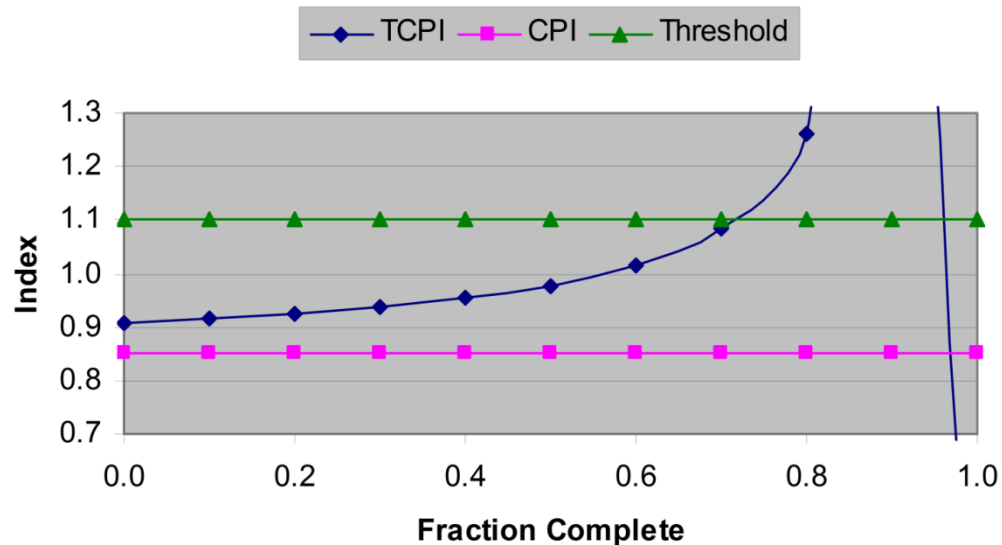
# Examination

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## TCPI & TSPI Behavior

# Examination / Behavior

- In 2009 TCPI was examined as to its behavior when the value approaches and then exceeds the value of 1.10



# Examination / Behavior

- As observed from the graph, TCPI increases gradually until its value is 1.10 ... from that point, TCPI and its rate of change becomes markedly larger for small increases in project fraction complete

EV%	TCPI	Rate of Change
0.714	1.100	1.131
0.750	1.149	1.614
0.800	1.259	3.032

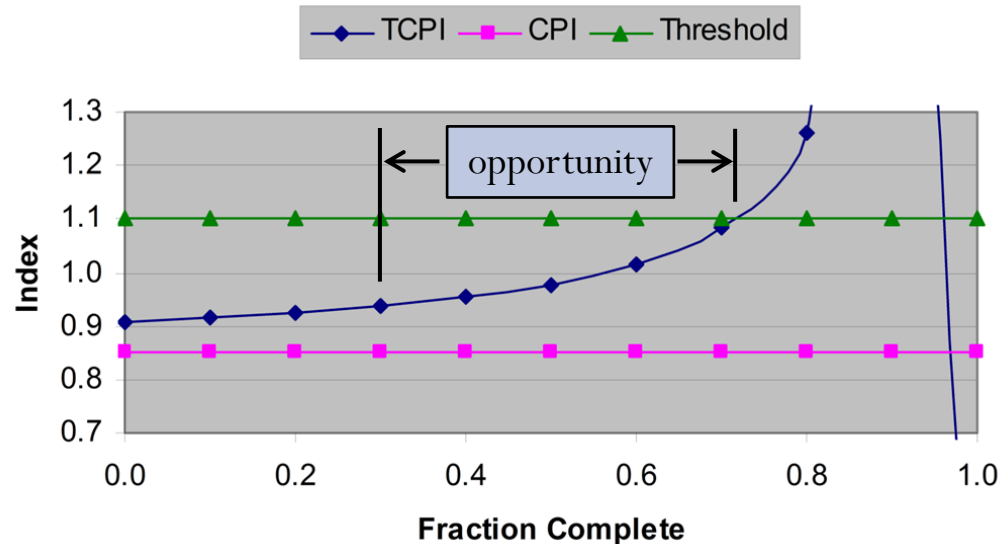
# Examination / Conclusion

- 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 303 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’”*
- 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

# Examination / Recovery

- Also, this investigation described how the “to complete” indexes could be used to determine the window of opportunity for project recovery





# Empirical Research

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## Testing TCPI/TSPI





# Empirical Research / Data

- EVM data from twenty five projects was used to evaluate the validity of the TCPI and TSPI threshold value, 1.10
- The project data came from three sources and was highly varied
- The projects ranged in duration from a few months to several years and had not undergone re-planning
- Analysis included effect of reserve amounts of 0, 5, 10, and 15 percent



# Empirical Research / Testing

- Hypothesis Testing – a statistical method for assessing the likelihood of the proposition
- Four hypothesis tests performed for each of the percentage levels (0, 5, 10, 15) for reserves:
  - Completion within budget is unlikely
  - Cost recovery is possible
  - On-time/early delivery is unlikely
  - Duration recovery is possible

# Empirical Research / Results

- The result from each of the TCPI hypothesis tests, regardless of reserve level, is  $H_a$ 
  - When  $TCPI \leq 1.10$  completion within the desired budget is likely
  - When  $TCPI > 1.10$  recovery to the desired budget is unlikely

Reserve	$TCPI \leq 1.10$	At/Under Budget	Test Statistic	$\alpha = 0.05$ Ho or Ha	$TCPI > 1.10$	Over Budget	Test Statistic	$\alpha = 0.05$ 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

# Empirical Research / Results

- Hypothesis test results of the TSPI threshold – all  $H_a$ , with one exception ...the sample size is only three projects ...none finished late, all completed on-time or early - in essence the  $H_a$  result
- Thus, TSPI results mirror those for TCPI
  - When  $TSPI \leq 1.10$  on-time/early delivery is likely
  - When  $TSPI > 1.10$  recovery to the desired duration is unlikely

Reserve	$TSPI \leq 1.10$	On Time / Early	Test Statistic	$\alpha = 0.05$ Ho or Ha	$TSPI > 1.10$	Late	Test Statistic	$\alpha = 0.05$ 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



# Probability of Recovery

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## Theory to Application



# Probability of Recovery/ Theory

- The probability that the mean (M) of a number of observations (O) is larger than a selected value (V):

$$X = (M - V) / (\sigma / \sqrt{n})$$

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

X = the statistically normalized difference of M minus V

$\sigma$  = the estimated standard deviation of the observed measures

n = the number of measures

$O_i$  = one of the observations

- Convert X to probability using normal or t-distribution

# Probability/ Dilemma

- To compute probability, two questions need answering:
  - *Are the values from the periodic measures of the index distributed normally?*
  - *Is the number of index measures finite?*
- Number of status values is limited by project completion, and therefore finite
  - *Finite adjustment factor:  $\sqrt[3]{((N - n) / (N - 1))}$*



# Probability/ Dilemma

- TCPI & TSPI exhibit odd behavior ...and lack of meaning for periodic values ...statistical distribution unknown
- The indexes do not satisfy the distribution requirement and we have a conundrum:

*How can the probability be computed without discerning  
the statistical characteristics of TCPI & TSPI?*



# Probability/ Resolution

- Set TCPI and TSPI = 1.10 and solve for CPI and SPI(t), respectively

$$CPI_T = 1.10 \text{ EV\%} / (1.10 \text{ CR} - 1 + \text{EV\%})$$

$$SPI(t)_T = 1.10 \text{ ES\%} / (1.10 \text{ SR} - 1 + \text{ES\%})$$

$$\text{where} \quad \text{EV\%} = \text{EV}/\text{BAC} \quad \text{ES\%} = \text{ES}/\text{PD}$$

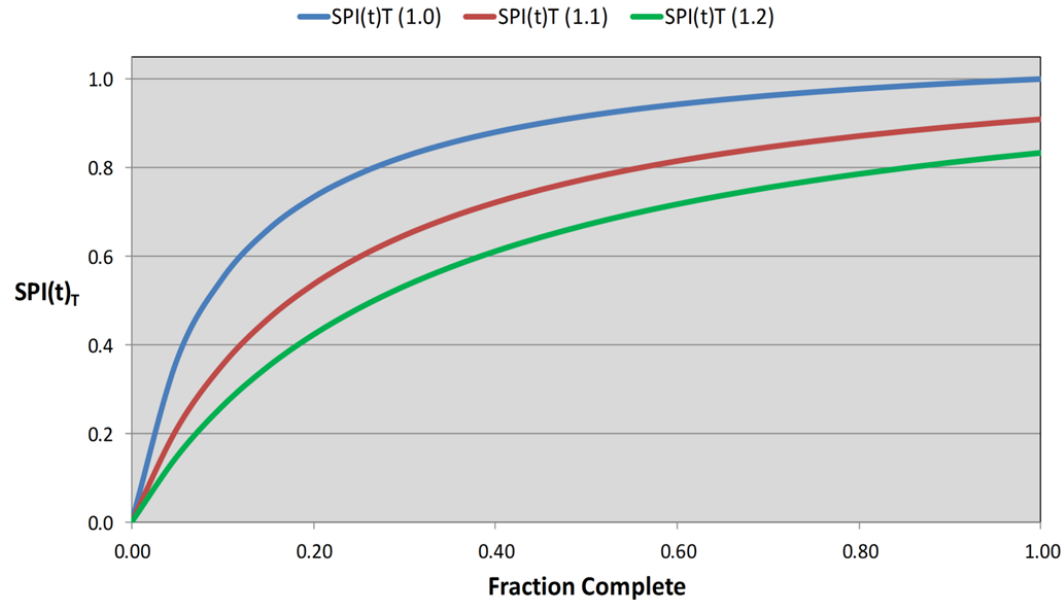
$$\text{CR} = \text{TC}/\text{BAC} \quad \text{SR} = \text{TD}/\text{PD}$$

- “T” functions facilitate comparison to performance indexes, CPI and SPI(t)
- When  $CPI < CPI_T$  or  $SPI(t) < SPI(t)_T$ , the threshold is breached

# Probability / Threshold Function



- Three plots illustrate the effect of various values of reserves



# Probability / Statistical Behavior



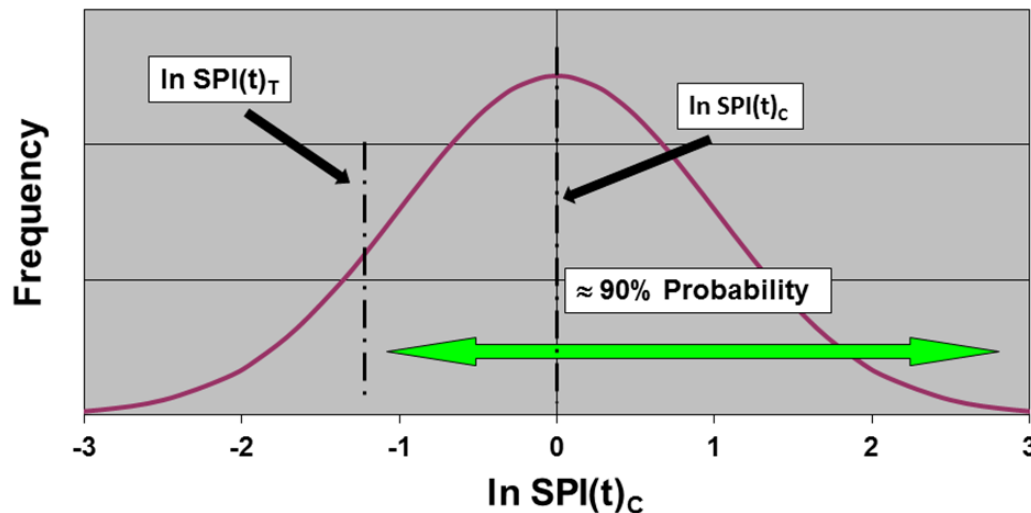
- Periodic values of CPI and SPI(t) are lognormally distributed
- The mean of the lognormal distribution is equal to the log of the cumulative index:

$$\ln \text{SPI}(t)_C = \Sigma(\ln \text{SPI}(t)_i) / n$$

- Thus, utilizing the  $\text{CPI}_T$  and  $\text{SPI}(t)_T$  functions, the statistical characteristics of CPI and SPI(t) facilitate computing the probability of recovery

# Probability / Example

- The probability is determined from the area beneath the normal curve beginning at  $\ln \text{SPI}(t)_T$  and extending to plus infinity



Scale shown in standard deviations

# Probability / Equations

- Cost & Schedule substitutions for variables,  $M$ ,  $V$ , and  $O_i$ :

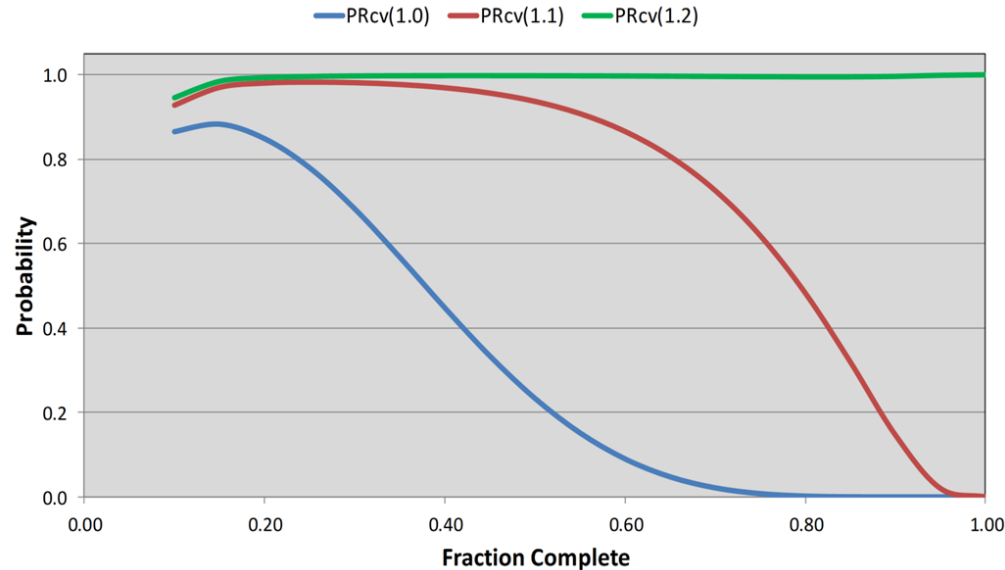
$$X = (M - V) / ((\sigma / \sqrt{n}) \bullet \sqrt{((N - n) / (N - 1))})$$

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

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

# Probability & Reserves

- The figure illustrates the influence of schedule reserve on the probability of recovery (PRcv)



# Probability / Application

- The examples and figures throughout have been presented in reference to schedule performance
- The discussion points are equally applicable to cost ...cost and schedule analysis are perfectly analogous
  - The threshold behavior of  $CPI_T$  is identical to the  $SPI(t)_T$  graph shown earlier
  - The interpretation of the probability example is unchanged when CPI is substituted for  $SPI(t)$
  - The PRcv graphs are identical for cost, when performance and risk reserve mimic the values employed for schedule



# Project Control

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## Project Management Use





# Project Control / Intervention

- Project Manager must balance inefficiency caused by intervention with the potential improvement
- Considerations in making decision
  - Sufficient data? ...too early in the execution?
  - Project recoverable? ...index value  $\leq 1.10$
  - Sufficient opportunity? ...window too small?
  - Probability of success? ...worth the risk?

# Project Control



## Probability of Recovery

# Project Control



## Prediction Analysis Calculator



# Project Control / Customer

- Analysis facilitates discussion with customer in status reviews
- Recovery analysis for late/over budget performance increases understanding
  - Recovery not likely
  - Window informs recovery possibility
  - Probability reinforces Window
  - Schedule recovery profile reasonable
- Negotiation for increases in delivery date and funding enhanced



# Summary

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## Application of TSPI (& TCPI)



# Summary / Index Value

- TCPI and TSPI underutilized by Project Managers
- Historic application of TCPI ...performance classification & EAC evaluation
- Index behavior investigation...graphical & numerical analysis
  - Project recovery is very unlikely when  $TSPI/TCPI > 1.10$
- Empirical testing ...1.10 value is a reliable threshold for both TCPI and TSPI



# Summary / Index Application

- Index threshold facilitates new performance analysis methods
- New methods enhance project control ...increasing likelihood of project success
  - Probability of recovery computation
  - Window of opportunity analysis
  - Schedule recovery improvement profile
- Facilitates Project Manager/Customer communication

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The image features a large, yellow oval with a dark red border. Inside the oval, the letters 'LES' are written in a large, stylized, dark red font. Overlaid on the 'LES' text is the phrase 'Thank You!!' in a black, sans-serif font. The background of the entire image is black.

Thank You!!

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