OKLAHOMA CITY CHAPTER

Earned Schedule

Deterministic

Project Duration Forecasting

Abstract

- Earned Schedule (ES), an extension to Earned Value Management (EVM), is a practice recognized in PMI® and ISO global standards. The time domain performance indicators for variance and efficiency, derived from ES, are deemed useful for project control. As well, ES facilitates project duration and completion date forecasting. Recent research indicates ES forecasting accuracy is generally improved when the performance factor equal to one (PF=1) is used. However, the ES schedule performance index, SPI(t), remains as accepted practice and, at times, provides the better deterministic forecast. It is postulated that there may be performance characteristics for identifying which of the calculation methods yields better accuracy. The presentation will discuss the investigation and research findings to discern those characteristics.

Objective

- Understand ES and its facility to provide schedule performance information
- Learn about the research that has led to improvements in duration forecasting
- Able to apply ES deterministic forecasting, to include the calculation selection method for improving accuracy

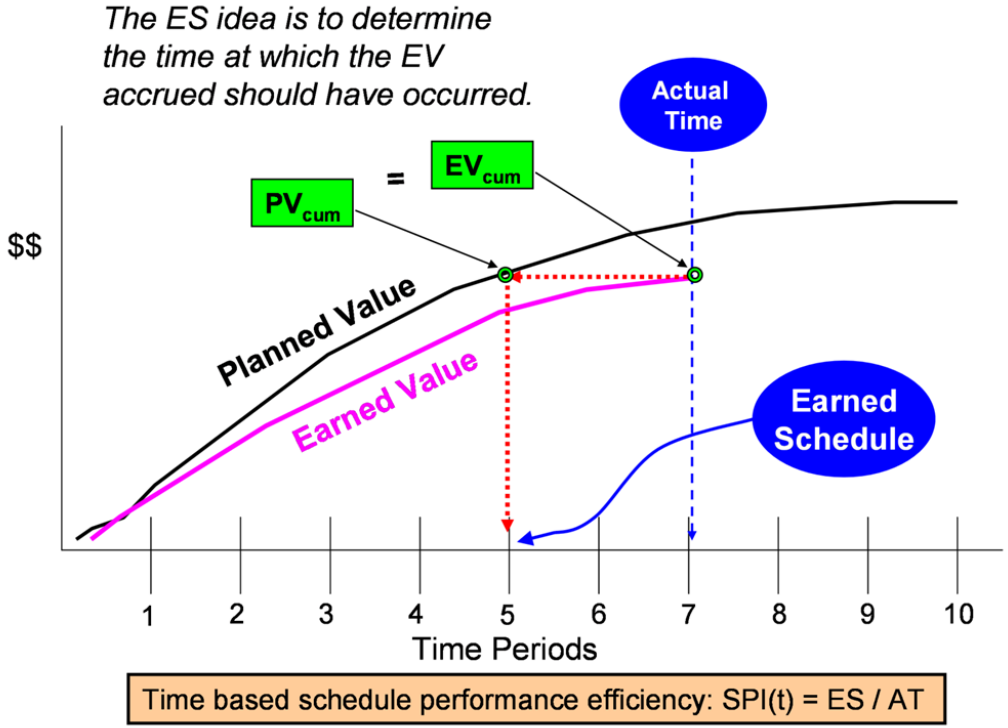
Overview

- Introduction
- Forecasting Research
- Why? - Investigation
- Analysis – Proposed Answer
- Simulated & Real Data Testing
- Summary/Conclusion
- Suggested Research

Introduction

Earned Schedule

Introduction / Earned Schedule



Earned Schedule Indicators

- Formula
  - $ES = C + I$

    where: C = number of time increments for $EV \geq PV_n$

    $$I = (EV - PV_C) / (PV_{C+1} - PV_C)$$
- Indicators
  - Schedule Variance: $SV(t) = ES - AT$
  - Schedule Performance Index: $SPI(t) = ES / AT$

Earned Schedule Forecasting

- Forecasting Formulas – Independent Estimate at Completion (time)
  - $IEAC(t) = PD / SPI(t)$

    where: PD = planned duration
  - $IEAC(t) = AT + (PD - ES)/PF_S$

    where: PF_S = performance factor - schedule

Earned Schedule Terminology

Metrics	Earned Schedule	ES_{cum}	ES = C + I number of periods (C), EV ≥ PV_C plus an incomplete portion (I)
	Actual Time	AT_{cum}	AT = number of periods executed
Indicators	Schedule Variance	SV(t)	SV(t) = ES – AT
		SV(t)%	SV(t)% = (ES – AT) / ES
	Schedule Performance Index	SPI(t)	SPI(t) = ES / AT
Predictor	To Complete Schedule Performance Index	TSPI	TSPI = (PD – ES) / (PD – AT)
			TSPI = (PD – ES) / (ED – AT)
Forecasts	Independent Estimate at Completion (time)	IEAC(t)	IEAC(t) = PD / SPI(t)
			IEAC(t) = AT + (PD – ES) / PF(t)
	Variance at Completion (time)	VAC(t)	VAC(t) = PD – IEAC(t) or ED

Forecasting Research

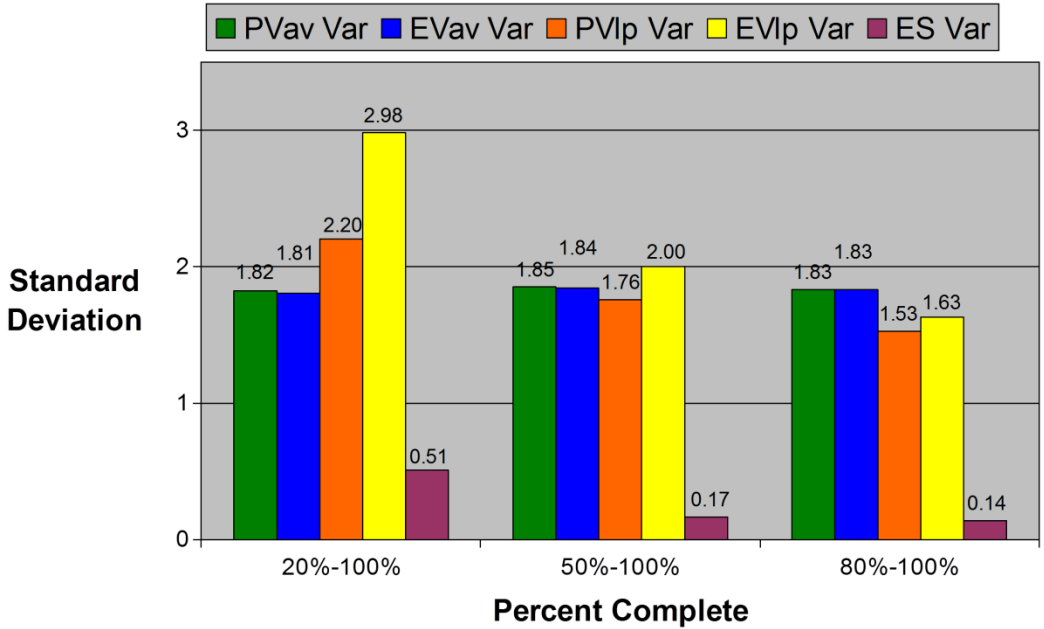
2003 - 2015

Forecasting Research/2003-15

- Creation of ES, indicators, and implication to forecasting
- Kym Henderson application to project portfolio / forecasting
- Vanhoucke & Vandevoorde simulations
  - Comparison to EVM methods …ES better
  - Schedule topology …serial most accurate
- Comparison versus EVM time conversion methods
- 'Longest Path' resolution to highly parallel schedules
- Creation of statistical forecasting method

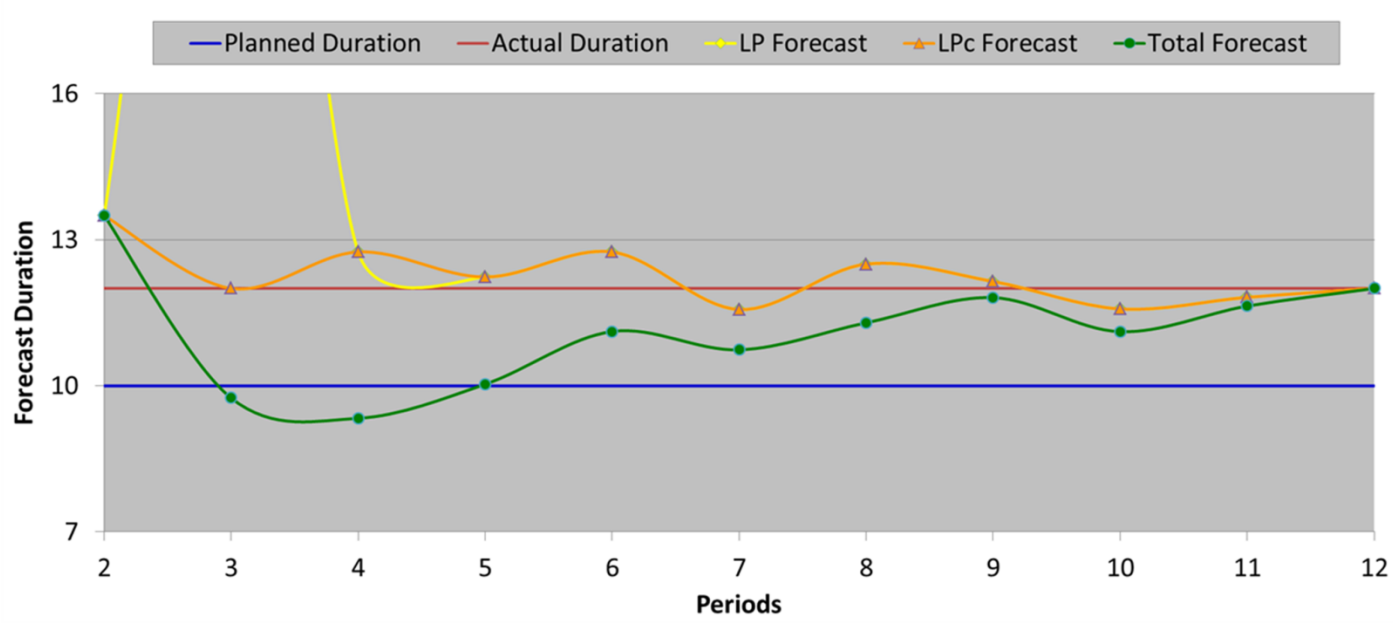
Forecasting Research/2003-15

- Comparison of ES versus EVM time methods



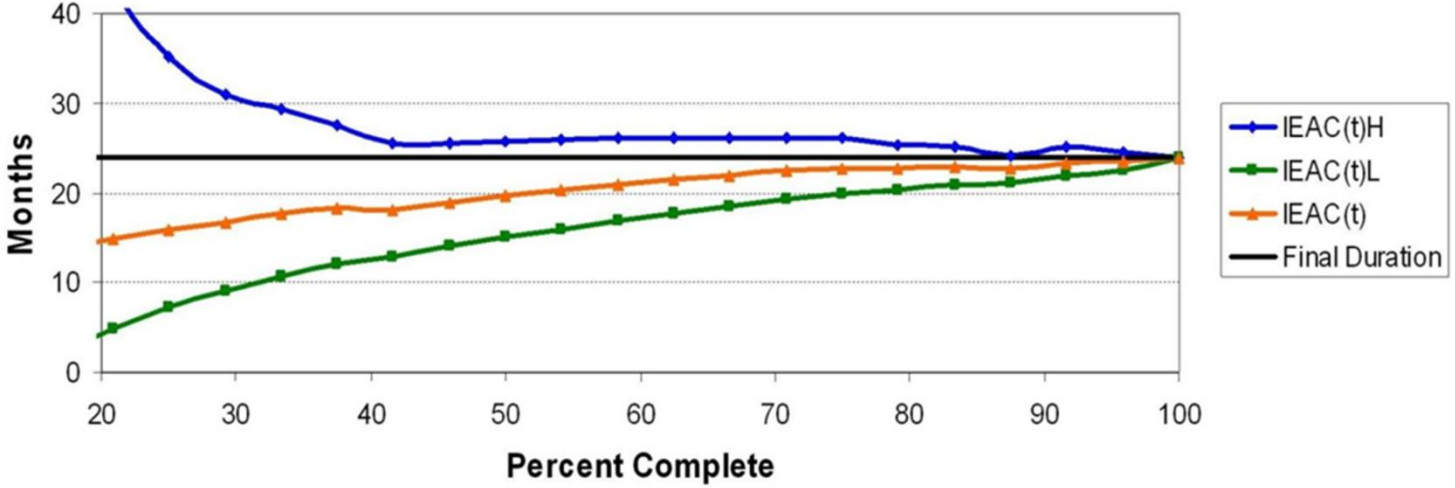
Forecasting Research/2003-15

- 'Longest Path' resolution to highly parallel schedules



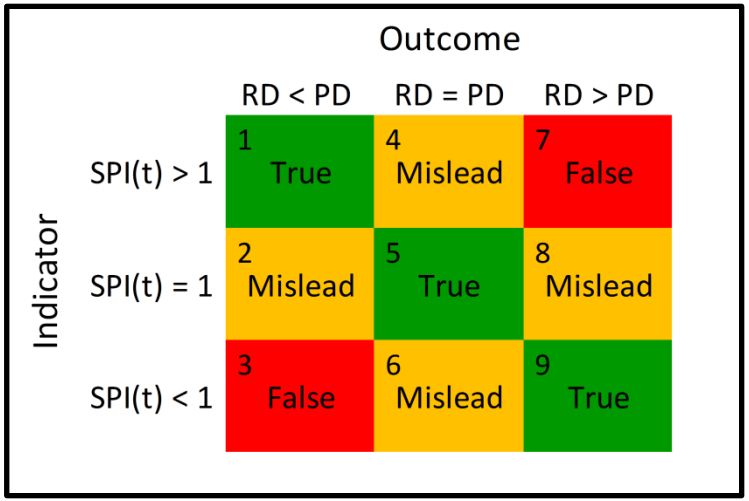
Forecasting Research/2003-15

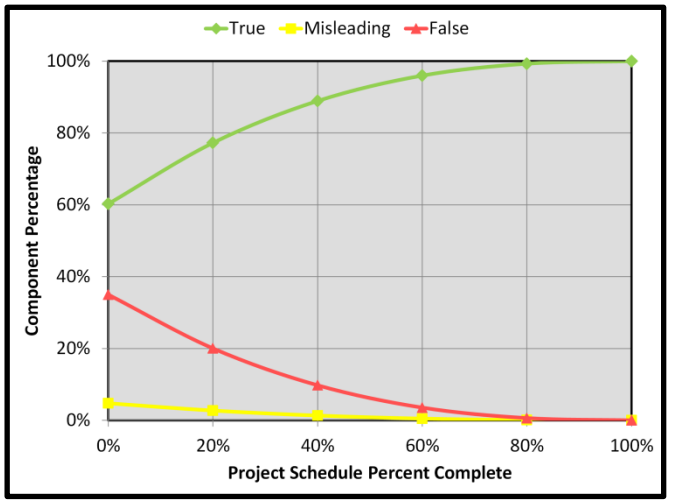
- Creation of statistical forecasting method



Forecasting Research/2003-15

- Vanhoucke investigates misleading and incorrect forecasts
- Forecast convergence characteristic minimizes misleading and incorrect forecast concern





Forecasting Research/2003-15

- Resolution to forecasting inaccuracy caused by stop work & down time interruptions
- Crumrine verifies ES forecasting using major defense projects
- Milestone forecasting created for large projects

Forecasting Research

Batselier & Vanhoucke (2015)

Forecasting Research / 2015…

- B & V comprehensively evaluated forecasting using EVM data from 51 projects, predominantly construction
- Alarmingly, results of the research demonstrated the use of performance factor, PF=1, with the ES method often provides the more accurate deterministic forecast
- B&V finding was corroborated, using 16 projects (IT & High Tech) …PF=1 was shown to provide better results for 12

Forecasting Research / 2015…

- Real data concerns
  - Do the data sets represent a very localized set of conditions? The data may be biased toward PF=1 forecasting
  - Are re-plans, stop work, and down time in the data? Each increases variation, causing SPI(t) to appear worse

Forecasting Research / 2015…

- Observations made in the 2nd study
  - When SPI(t) is constant, its forecast is superior
  - With highly variable performance, PF=1 is more accurate
- Further research was suggested …to gain an understanding of 'Why PF=1 appears better?'

Why PF=1 Better?

Investigation

PF=1 Better? / Investigation

- Two step process
  - Step 1 - Compile data from simulating performance of 25 projects using 39 scenarios of variation and early/late bias
  - Step 2 - Inspect the tabulated results for patterns favoring one of the forecasting methods, PF=1 or SPI(t)

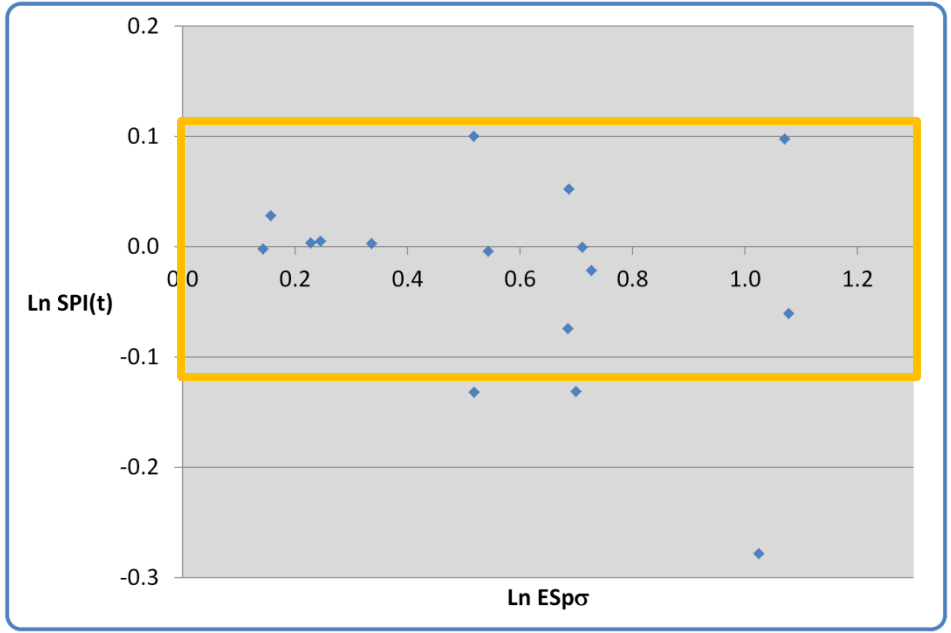
PF=1 Better? / Investigation

- Step 1 – Compiled Results (example)

	Scenario Inputs							Outcome Averages			Error Results	
Scenario	SPI(t)	PD	Fixed Var	F or V	Var Mult	Bias "+"	Trigger	FD	lnESp σ	lnSPI(t)	MAPE(1)	MAPE(S)
B1	1.000	44	NA	V	0.10	0.10	0.10	46	0.157	-0.034	0.0297	0.0156
B2	1.000	35	NA	V	0.50	0.10	0.10	44	0.299	-0.199	0.1087	0.0463
B3	1.000	24	NA	V	0.90	0.10	0.10	36	0.678	-0.384	0.1694	0.0899
B4	1.000	45	NA	V	0.10	0.50	0.10	46	0.143	-0.002	0.0118	0.0126
B5	1.000	42	NA	V	0.50	0.50	0.10	43	0.336	0.003	0.0271	0.0413
B6	1.000	39	NA	V	0.90	0.50	0.10	40	0.711	-0.001	0.0427	0.0660
B7	1.000	48	NA	V	0.10	0.90	0.10	47	0.126	0.036	0.0126	0.0126
B8	1.000	52	NA	V	0.50	0.90	0.10	44	0.256	0.153	0.0836	0.0295
B9	1.000	56	NA	V	0.90	0.90	0.10	42	0.443	0.287	0.1510	0.0454

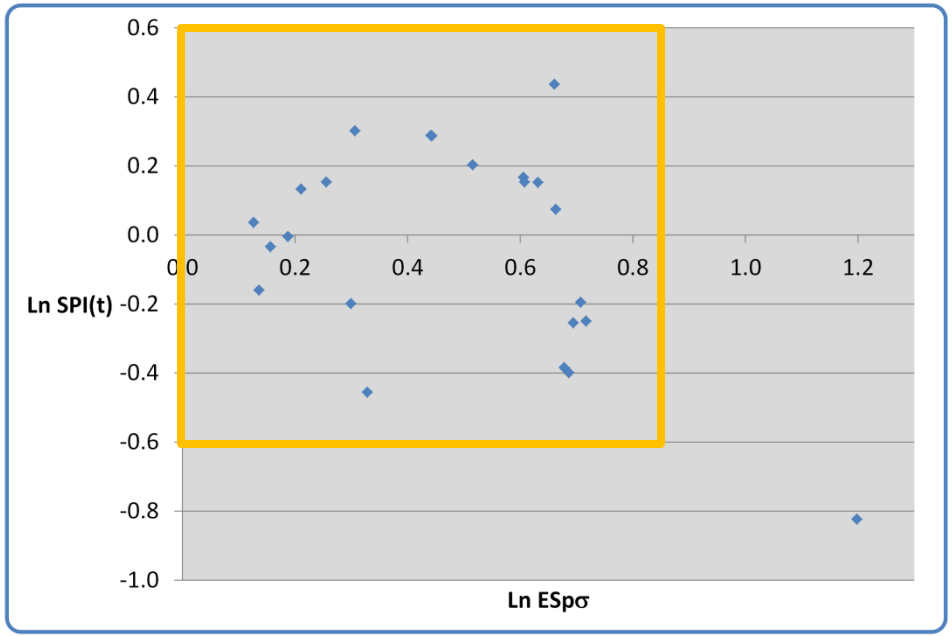
PF=1 Better? / Investigation

- Step 2 – PF=1 forecast better, 16 outcomes



PF=1 Better? / Investigation

- Step 2 – SPI(t) forecast better, 23 outcomes



Analysis

Proposed Answer

Analysis / Answer

- Forecast formula selection rules

SPI(t) & PF=1 Selection Rules		
Use PF=1	when	$-0.1 \leq \ln SPI(t) \leq 0.1$ & $\ln ESp\sigma \leq 0.8$
Use SPI(t)	when	$0.6 \geq \ln SPI(t) > 0.1$ & $\ln ESp\sigma \leq 0.8$
Use SPI(t)	when	$-0.6 \leq \ln SPI(t) < -0.1$ & $\ln ESp\sigma \leq 0.8$
Use PF=1	when	$-0.6 > \ln SPI(t) > 0.6$ or $\ln ESp\sigma > 0.8$ = Out of Control

Testing

Simulated & Real Data

Testing / Simulated Data

Simulated Data										
Project	1	2	3	4	5	6	7	8	9	10
PD	24	56	66	39	25	29	35	39	35	52
FD	34	41	43	47	43	33	38	37	43	45
# Out of Cntrl	0	0	0	0	3	0	13	0	0	0
Err-SPI(t)	0.082	0.029	0.064	0.012	0.049	0.061	0.082	0.049	0.040	0.023
Err-PF1	0.162	0.167	0.213	0.082	0.209	0.050	0.030	0.033	0.099	0.074
Err-Selection	0.083	0.029	0.064	0.012	0.065	0.068	0.036	0.051	0.043	0.034
Err-Best	0.081	0.027	0.057	0.012	0.049	0.032	0.023	0.026	0.040	0.021

Testing / Real Data

Real Data										
Project	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PD	21	32	43	24	41	29	43	17	44	42
FD	24	38	47	24	50	30	50	23	50	50
# Out of Cntrl	3	0	23	0	22	0	31	0	20	2
Err-SPI(t)	0.187	0.090	0.134	0.041	0.077	0.067	0.058	0.138	0.156	0.100
Err-PF1	0.129	0.093	0.050	0.015	0.071	0.034	0.067	0.131	0.067	0.093
Err-Selection	0.156	0.093	0.111	0.031	0.086	0.063	0.064	0.149	0.124	0.096
Err-Best	0.125	0.075	0.039	0.015	0.044	0.034	0.039	0.103	0.056	0.070

Testing / Composite

Simulated Data										
Project	1	2	3	4	5	6	7	8	9	10
S & 1 within 5%?	no	no	no	no	no	yes	no	no	no	no
S or 1 Better?	S	S	S	S	S	1	1	1	S	S
Select Improve?	yes	yes	yes	yes	yes	no	yes	no	yes	yes

Real Data										
Project	1	2	3	4	5	6	7	8	9	10
S & 1 within 5%?	no	yes	no	yes	yes	yes	yes	yes	no	yes
S or 1 Better?	1	S	1	1	1	1	S	1	1	1
Select Improve?	yes	yes	yes	yes	no	yes	yes	no	yes	yes

Summary/Conclusion

Summary / Conclusion

- Two empirical studies reported that PF=1 provides better project duration forecasts than SPI(t)
- There are instances where SPI(t) was better … thus, performance conditions may cause one method to forecast more accurately
- Simulation of 25 projects, applying 39 performance scenarios, revealed graphical patterns

Summary / Conclusion

- From the graphical patterns selection rules were derived

SPI(t) & PF=1 Selection Rules		
Use PF=1	when	$-0.1 \leq \ln SPI(t) \leq 0.1$ & $\ln ESp\sigma \leq 0.8$
Use SPI(t)	when	$0.6 \geq \ln SPI(t) > 0.1$ & $\ln ESp\sigma \leq 0.8$
Use SPI(t)	when	$-0.6 \leq \ln SPI(t) < -0.1$ & $\ln ESp\sigma \leq 0.8$
Use PF=1	when	$-0.6 > \ln SPI(t) > 0.6$ or $\ln ESp\sigma > 0.8$ = Out of Control

- Selection rules were tested using simulated and real data
- For both data sets, the selection rules for 8 of 10 projects yielded more accurate forecasts than at least one of the PF=1 and SPI(t) methods.

Summary / Conclusion

- The two deterministic methods yield very comparable forecasts about 70 percent of the time
- The risk of using the PF=1 method is there are instances when its forecast can be in error by greater than 10 percent
- The risk of exclusively using SPI(t) forecasting is it generally has larger error than PF=1, although the difference is small.

Suggested Research

Suggested Research

- The duration forecasting selection rules proposed should be further examined before general adoption
- It is suggested that those practitioners having real data apply the rules and report their findings
- Application of the selection rules to simulated EVM data is welcomed, and may yield refinements or a better approach
- For those interested, the forecast method selection spreadsheet is available from the ES website (www.earnedschedule.com)

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