Project Duration Forecasting

a comparison of EVM methods to ES

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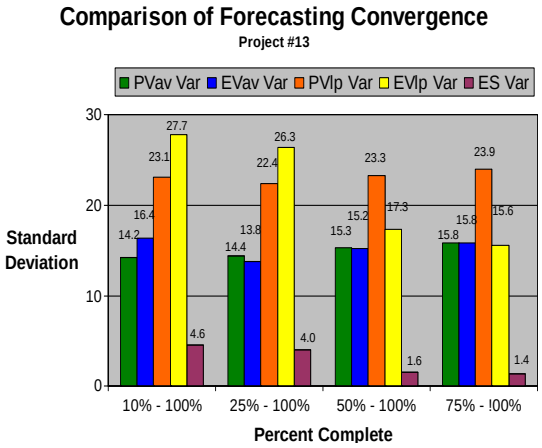

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Abstract

- EVM methods for forecasting project duration are generally accepted practice, yet they have not been well studied as to their predictive capability.
- Using real project data, four EVM methods are examined and compared to the Earned Schedule prediction technique.

Overview

- Introduction
- EVM & ES Duration Forecasting
- Discussion of Methods & Considerations
- Study Hypothesis & Methodology
- Data Description
- Results & Analysis
- Summary & Conclusions

Introduction

- Earned Schedule introduced in 2003
  - Time-based indicators for schedule
- ES extended to duration forecasting in 2004
- Two efforts explored the capability of ES forecasting
  - Case study of US Navy project
  - Comprehensive examination of two EVM-based methods and ES using simulation

Introduction

- *"The results ..confirm ..that the ES method outperforms, on average, the other forecasting methods"* - Vanhoucke & Vandevoorde
- Results are supportive of ES, but there are lingering questions
  - *Does simulation, albeit comprehensive, truly represent real project circumstances?*
  - *Is broad validation possible from the single case study and other sporadic application results?*

Introduction

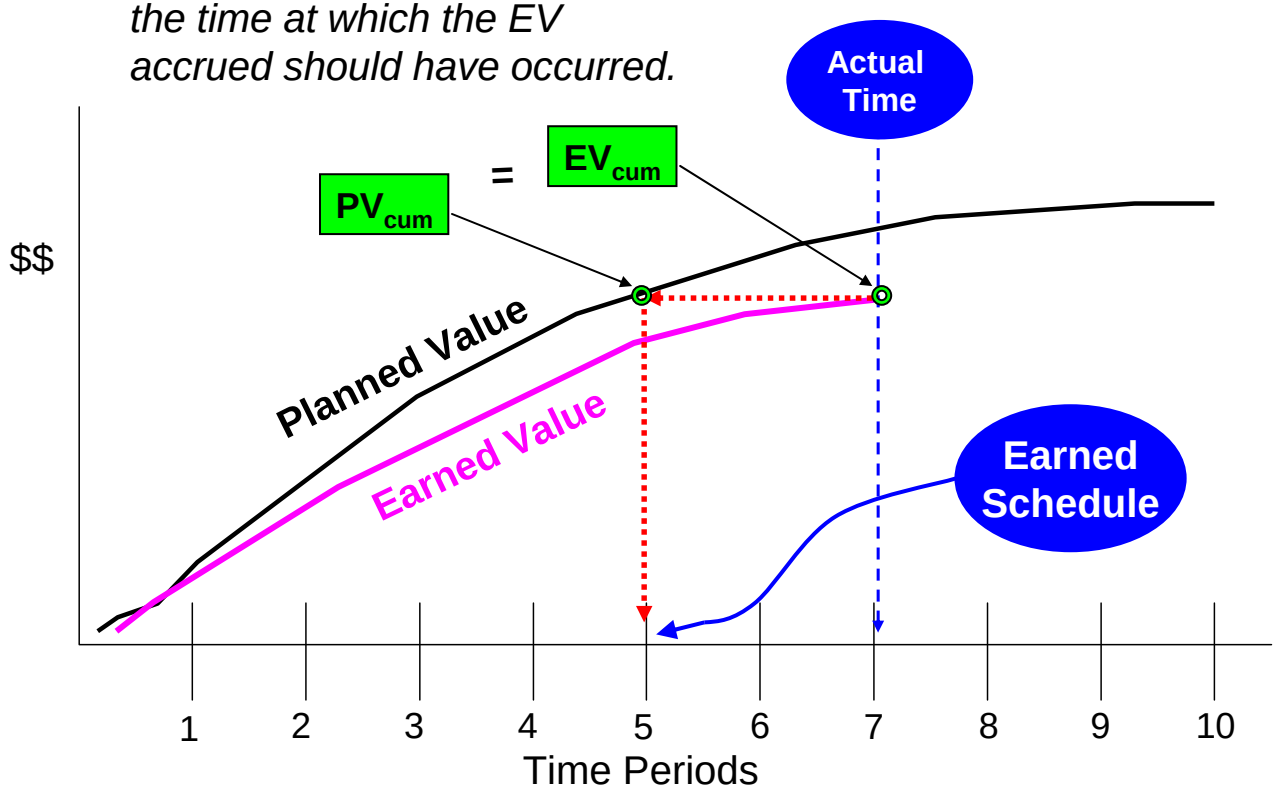
- Results for ES have been studied to some degree …but traditional EVM forecasting methods have not
- To bridge these gaps, the forecasting capabilities of four EVM duration forecasting methods are compared to the results for ES using data from 16 projects

EVM & ES Duration Forecasting

- Four EVM duration forecasting techniques have been commonly applied for 40 years
- The EVM methods have the basic form
  - *Duration Forecast = Elapsed Time + Forecast for Work Remaining*
  - *IEAC(t) = AT + (BAC – EV) / Work Rate*
- Four Work Rates –
  - *Average Planned Value: PVav = PVcum / n*
  - *Average Earned Value: EVav = EVcum / n*
  - *Current Period Planned Value: PVlp*
  - *Current Period Earned Value: EVlp*

EVM & ES Duration Forecasting

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

EVM & ES Duration Forecasting

- Final cost forecast from EVM –
  - *IEAC = BAC / CPI*

- Similarly final duration is forecast using ES –
  - *IEAC(t) = PD / SPI(t)*

    where PD is the planned duration of the project

Methods & Considerations

- The EVM methods have mathematical failings
- When a project executes past its planned duration –
  - PVcum = BAC and increases no further
  - PVav = BAC / m …where m is larger than N, the number of periods of the plan
  - As m increases, PVav decreases causing forecast for work remaining to be longer than its planned time

Methods & Considerations

- When a project executes past its planned duration –
  - For PVlp no periodic values exist beyond the PD
  - Calculation of IEAC(t) is indeterminate
  - These periods are excluded from the analysis …the earlier forecasts may be good
  - Desire is to allow each method to show well, despite its limitations

Methods & Considerations

- Work rates, EVav and EVlp, normally do not have indeterminate conditions
- One exception – *small projects assessing status weekly* – may have periods for which no EV is accrued
  - When this occurs, EVlp = 0 and the associated IEAC(t) is indeterminate
  - Indeterminate condition is accommodated by using previous valid observation

Methods & Considerations

- Forecasting using ES does not experience indeterminate calculation conditions
- With exception for the forecast using PVlp, all forecasting calculation methods studied converge to the actual final duration

Study Hypothesis & Methodology

- The Earned Schedule method for forecasting final duration is believed to be better than the four traditional EVM methods
- The test for the conjecture is constructed to show that the aggregate of the EVM methods produce better forecasts than does ES
  - If EVM methods prove superior, further examination is necessary to identify which method is applicable for a set of conditions

Study Hypothesis & Methodology

- The hypothesis is formally defined as
  - *Ho: EVM methods produce the better forecast of final project duration*
  - *Ha: ES method produces the better forecast of final project duration*
- Ho is termed in the jargon of statistics as the "null hypothesis" …it is the statement to be validated
- Ha is the alternate hypothesis

Study Hypothesis & Methodology

- The statistical testing is performed using the *Sign Test* applied at 0.05 level of significance
- Assuming each method has an equal probability of success, the probability for each trial is 0.8
- The test statistic for the hypothesis test is computed from the number of times the EVM methods yield the better forecast
  - With 16 projects, the maximum number of successful trials is 16
  - When EVM successes are fewer than 10, the test statistic value is in the critical region …there is enough evidence to reject the null hypothesis

Study Hypothesis & Methodology

- The test statistic is determined from the ranking of the standard deviation for each of the five methods
  - Standard deviation is computed from the variation between forecast values and the actual final duration
  - Smallest standard deviation is ranked “1”

    …largest is “5”
  - Number of times the EVM methods are ranked “1” without ties determines the test statistic value
  - The ranking approach normalizes the differences in time units between projects

Study Hypothesis & Methodology

- To better understand and distinguish between forecasting methods, the projects are tested and analyzed for seven performance regions
  - Early – 10% to 40% complete
  - Middle – 40% to 70% complete
  - Late – 70% to 100% complete
  - Overall – 10% to 100% complete
  - Converge Early – 25% to 100%
  - Converge Middle – 50% to 100%
  - Converge Late – 75% to 100%

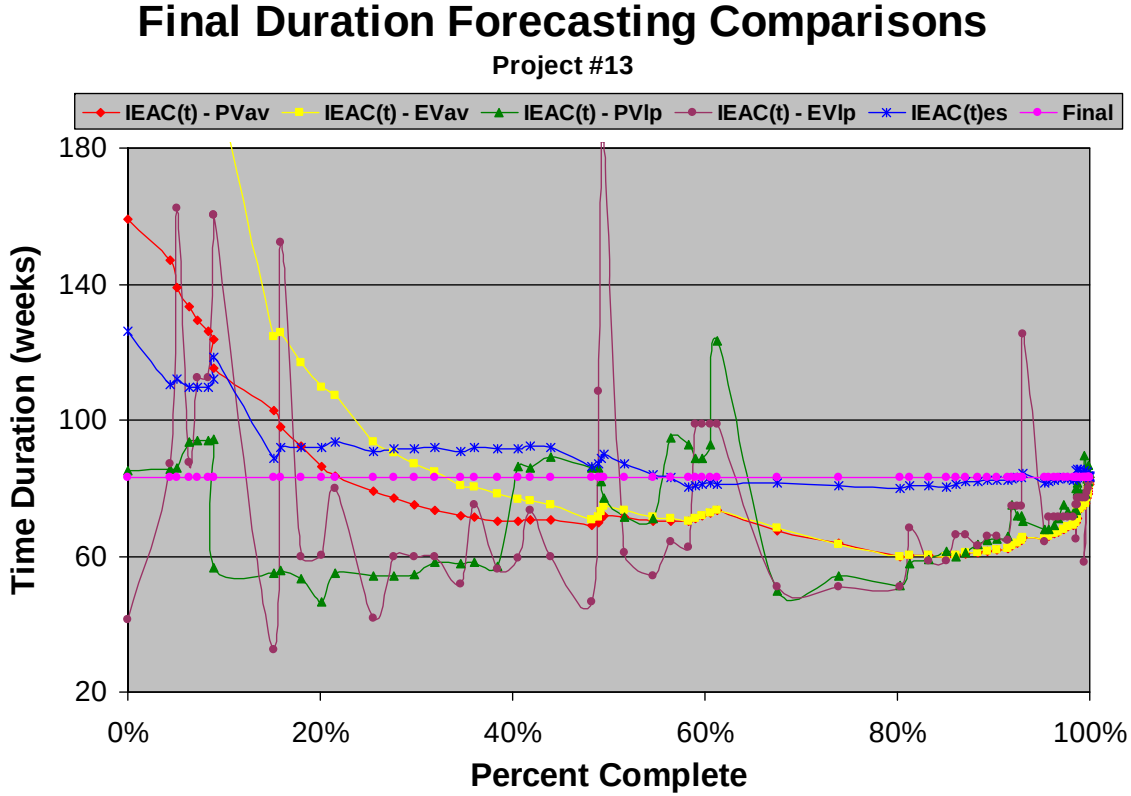
Data Description

- Data from 16 projects are used in the testing and analysis …12 high tech and 4 IT
- High tech projects have monthly periods while the IT projects were measured weekly
- Two projects completed early, three on time and eleven were late – *none had re-plans*

Schedule Performance								
Project	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Planned Duration	21m	32m	36m	43m	24m	50m	46m	29m
Actual Duration	24m	38m	43m	47m	24m	59m	54m	30m
Project	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Planned Duration	45m	44m	17m	50m	81w	25w	25w	19w
Actual Duration	55m	50m	23m	50m	83w	25w	22w	13w
Legend: m = month w = week								

Results & Analysis

- The graph below is an example of the performance of all five forecasting methods along with a plot of the actual final duration

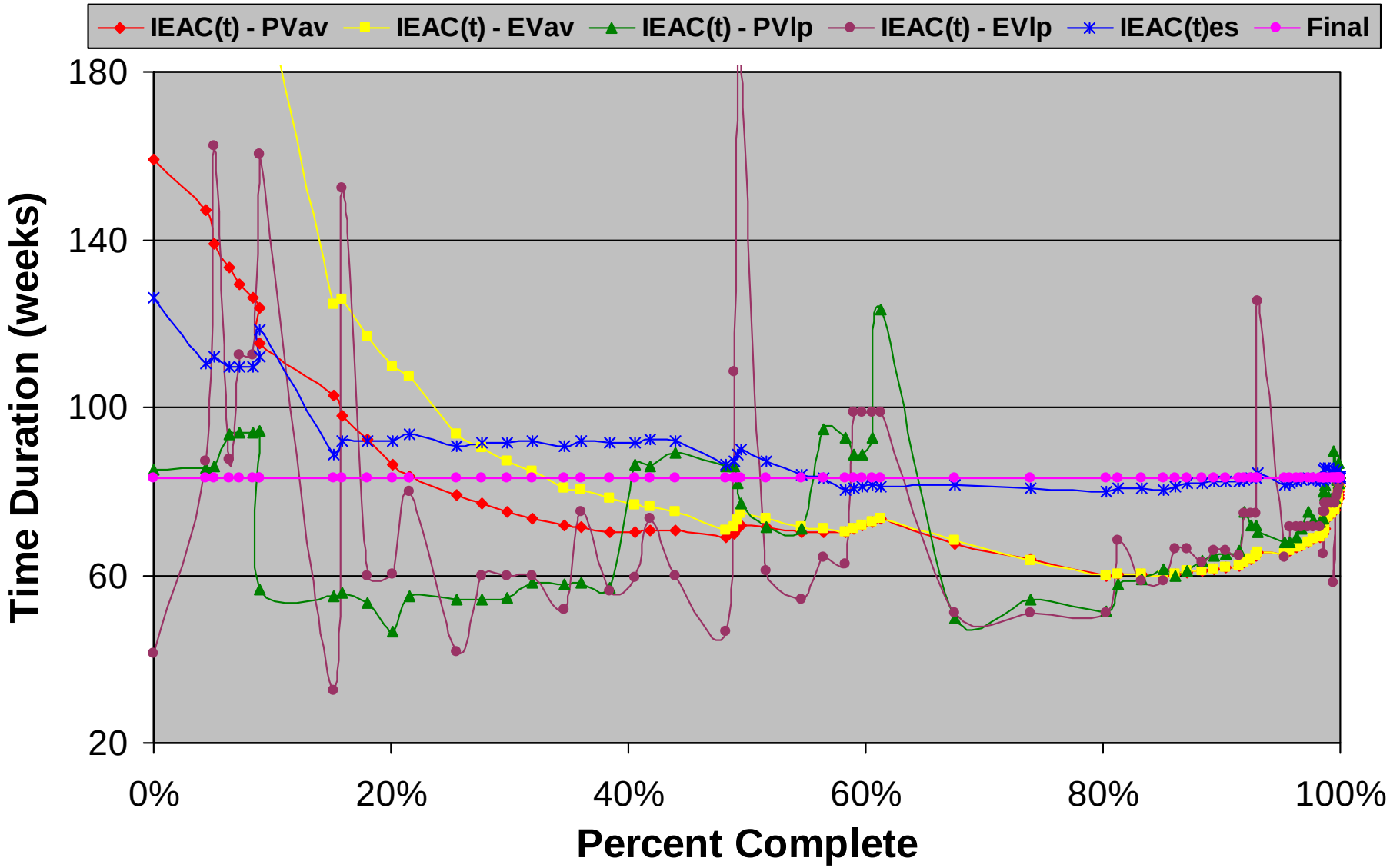


Results & Analysis

- Forecast characteristics observed –
  - PVlp and EVlp work rates produce volatile results
  - PVav and EVav work rates are smoother
  - ES forecast is much better, especially after 40% complete …after 60% the forecast is very close to the final duration

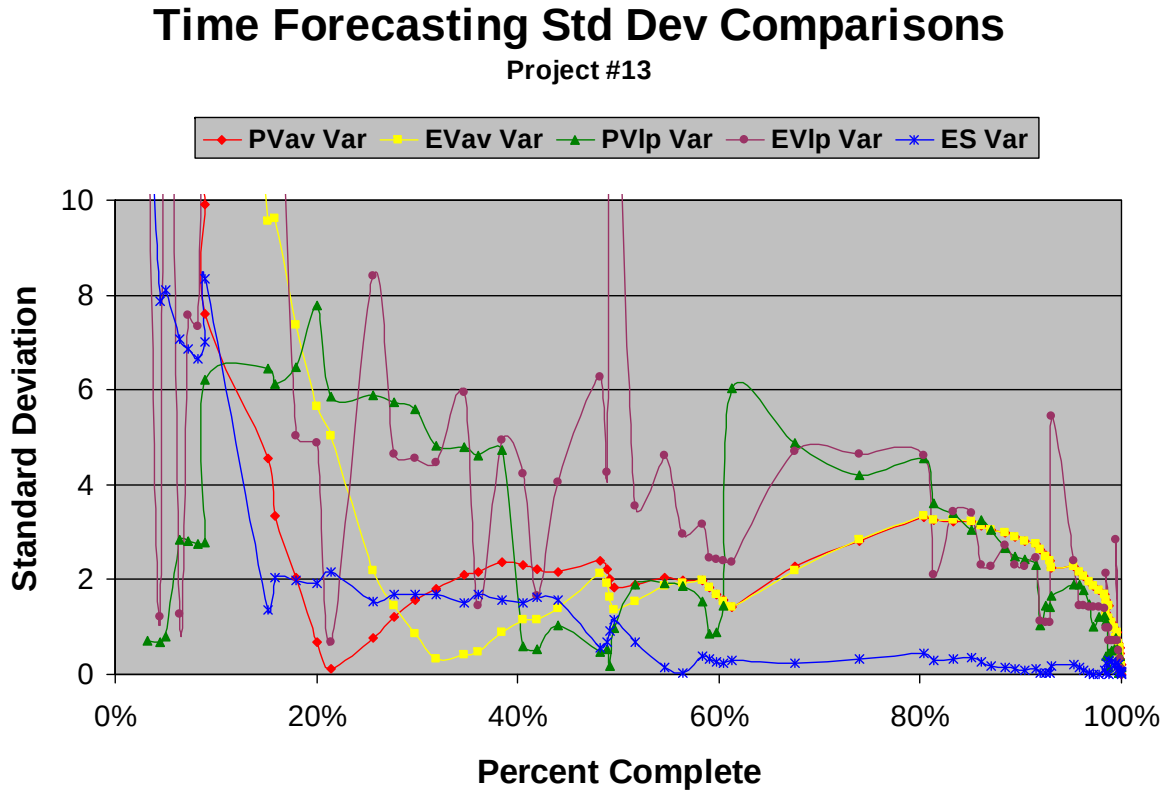
Final Duration Forecasting Comparisons

Project #13



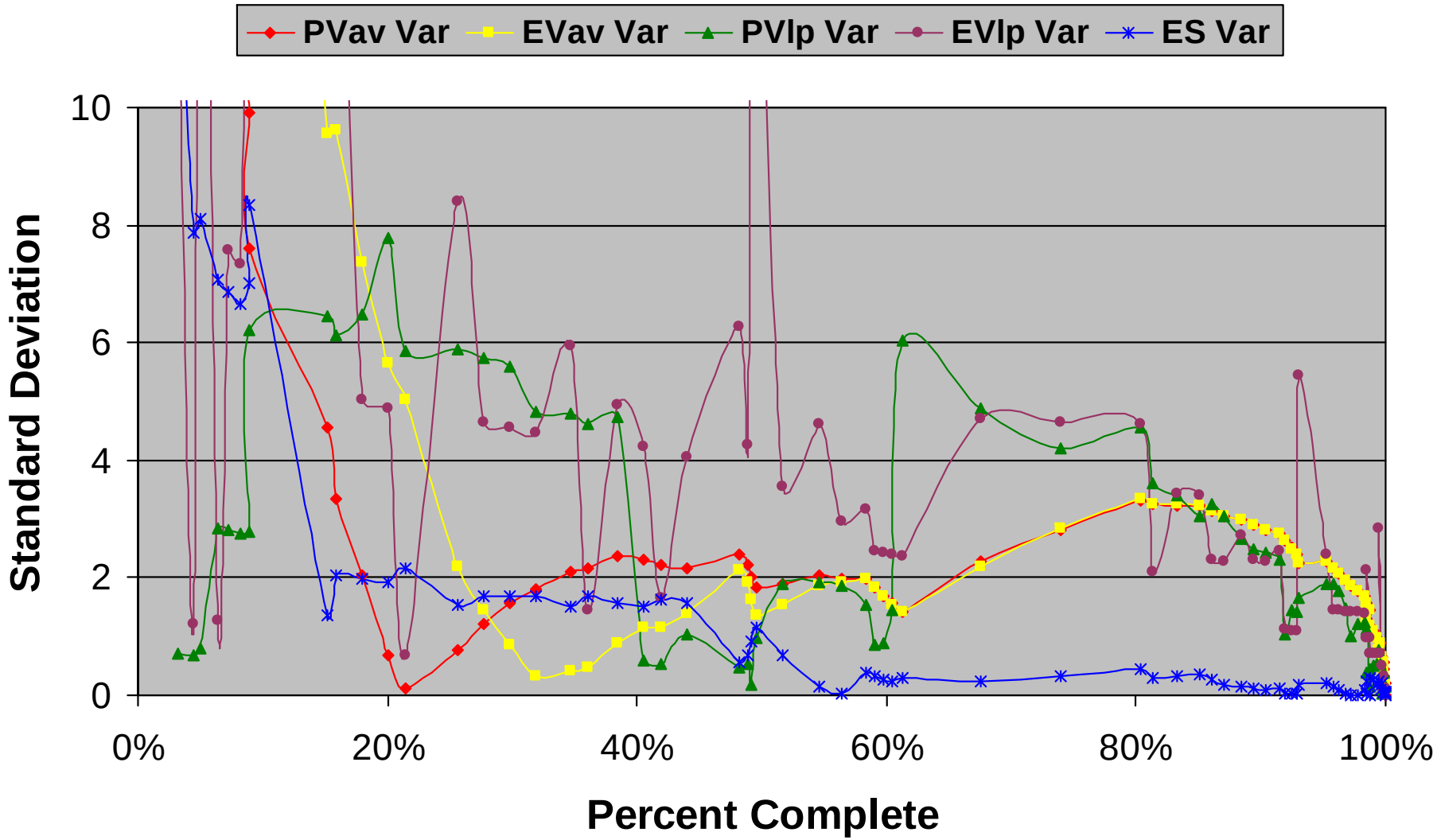
Results & Analysis

- The plot of standard deviation amplifies the view of the final duration comparisons



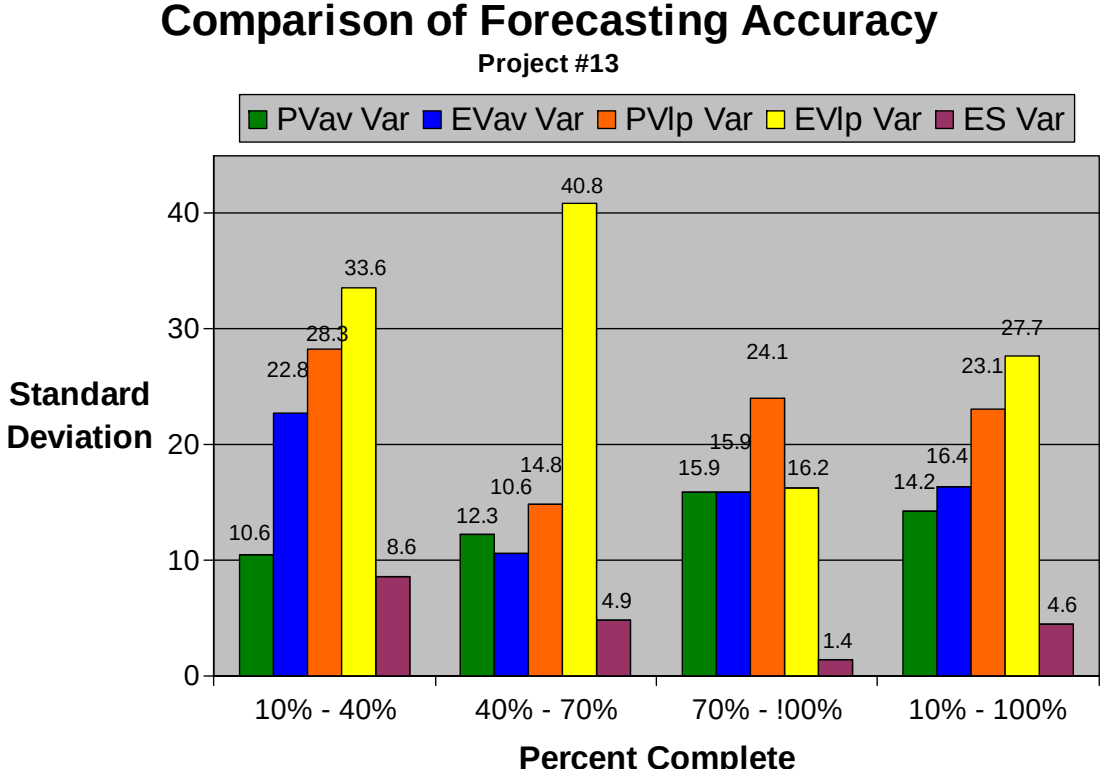
Time Forecasting Std Dev Comparisons

Project #13



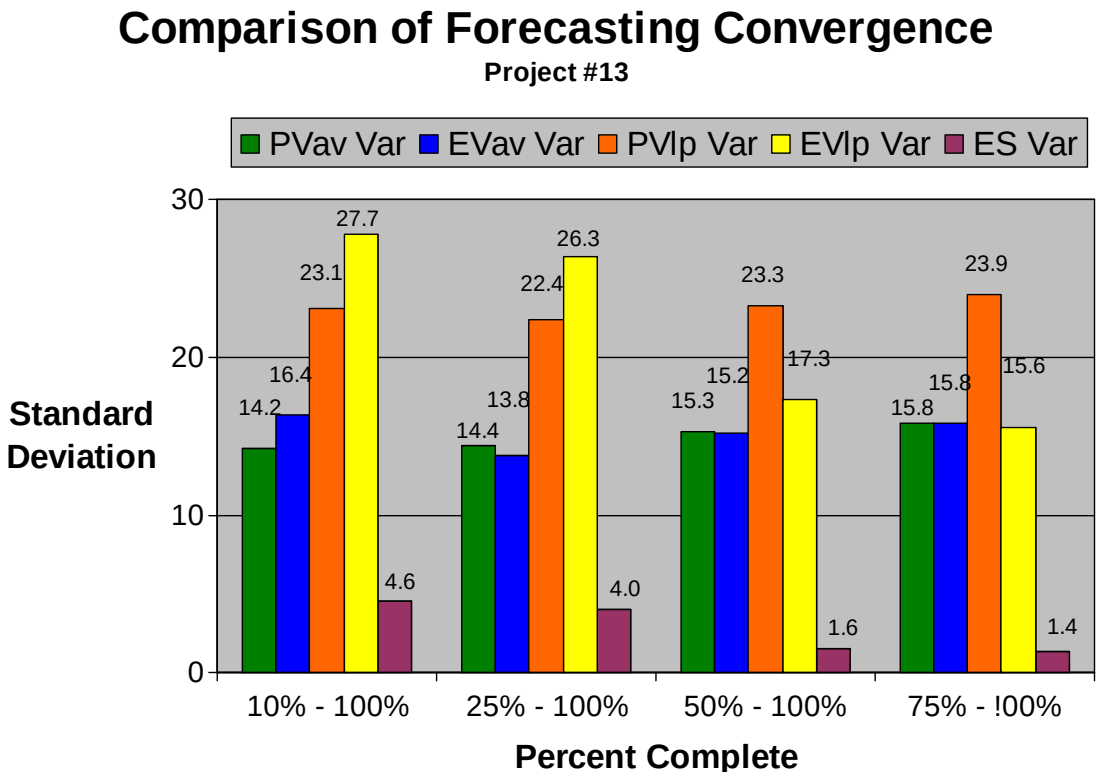
Results & Analysis

- The column graph of the project data more clearly illustrates the behavior for early, middle, late and overall groupings



Results & Analysis

- The column graph assists examination of convergence characteristic



Results & Analysis

- The column graphs indicate, as expected, that the current period forecasting methods, EVlp & PVlp, produce more volatile results
- For the project depicted, the ES forecast is the superior predictor in every range examined
- The expectation of decreasing standard deviation as the percent complete range is increasingly focused toward completion is observed for ES and EVlp, only
  - The characteristic is seen for PVav & EVav …but is not strongly evident until after 80% complete *(refer to line graphs)*

Results & Analysis

- Below is an example of the compilation of the standard deviations and rankings for the 10% - 40% grouping

Standard Deviation Results & Ranking for 10% - 40% Completion Group													
Project ID		Project #1		Project #2		Project #3		Project #4		Project #5		Project #6	
		Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank
Methods	PVav	14.95	5	13.01	4	11.93	2	25.59	2	4.38	2	29.76	2
	EVav	2.65	1	9.35	2	8.28	1	48.68	4	5.82	3	42.64	4
	PVlp	5.47	2	13.62	5	77.74	5	42.77	3	8.67	4	42.11	3
	EVlp	6.00	3	12.14	3	22.38	3	103.15	5	9.89	5	263.03	5
	ES	8.28	4	4.78	1	46.76	4	14.03	1	1.88	1	3.57	1
Project ID		Project #7		Project #8		Project #9		Project #10		Project #11		Project #12	
		Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank
Methods	PVav	9.79	3	16.16	3	6.75	2	9.06	1	7.66	4	15.06	3
	EVav	6.00	2	33.17	5	15.63	3	10.55	2	6.63	3	30.49	5
	PVlp	17.95	5	20.69	4	20.80	4	39.11	4	7.70	5	9.06	1
	EVlp	15.07	4	5.69	2	525.62	5	102.21	5	6.58	2	26.86	4
	ES	4.31	1	5.09	1	3.74	1	15.22	3	4.54	1	12.49	2
Project ID		Project #13		Project #14		Project #15		Project #16					
		Std Dev	Rank	Std Dev	Rank	Std Dev	Rank	Std Dev	Rank				
Methods	PVav	10.57	2	2.36	1	15.93	3	20.18	5				
	EVav	22.78	3	5.90	5	18.12	5	17.10	4				
	PVlp	28.25	4	2.36	1	11.24	2	12.37	2				
	EVlp	33.59	5	5.49	4	16.87	4	16.49	3				
	ES	8.62	1	4.46	3	4.45	1	5.20	1				

Results & Analysis

- For the table shown, the rank for the ES method is “1” for eleven projects …a large majority …even so, we see that the ES forecast is not best for every project
- Every range is examined in the same way …to have a more complete understanding of how the various forecasting methods perform under differing circumstances

Results & Analysis

- To more clearly understand the performance of the 5 forecasting methods the ranking results are condensed into tables for each data grouping …below is an example
- The distribution of results are used to compute a weighted average for assessing the overall performance for each method

Rank Count for Data Group 10% - 40%						
		Methods				
		PVav	EVav	PVlp	EVlp	ES
Count	Nr 1s	2	2	2	0	11
	Nr 2s	6	3	3	2	1
	Nr 3s	4	4	2	4	2
	Nr 4s	2	3	5	4	2
	Nr 5s	2	4	4	6	0
Weighted Average		2.750	3.250	3.375	3.875	1.688
Composite Rank		2	3	4	5	1

Results & Analysis

- Displayed below is a tabulation of the weighted averages of the rankings for all data ranges examined
- The ES method has the lowest value for every range. Only the PVav method is close for the 40% - 70% data grouping

Weighted Average of Ranking Results - EVM vs ES Time Forecast							
	**********		Percent Complete Test Bands			**********	
	10% - 40%	**40% - 70%**	**70% - 100%**	**10% - 100%**	**25% - 100%**	**50% - 100%**	**75% - 100%**
ES	1.688	2.063	1.438	1.625	1.563	1.563	1.438
PVav	2.750	2.500	3.688	2.625	2.813	3.063	3.875
EVav	3.250	2.813	2.938	3.000	3.063	2.938	2.875
PVlp	3.375	3.438	3.875	3.813	3.875	3.688	3.875
EVlp	3.875	4.188	3.063	3.938	3.688	3.750	2.938

Results & Analysis

- The results of the statistical hypothesis testing is compiled in the table below
- With the exception of the 40% - 70% range, the ES method is clearly superior to the EVM methods combined …the test statistic is in the critical region, thereby rejecting the Ho hypothesis
- The ES method is shown to be the better forecasting method, regardless of project completion stage

Hypothesis Test Results - EVM vs ES Time Forecast								
Significance		**********	Percent Complete Test Bands				**********	
α = 0.05		**10% - 40%**	**40% - 70%**	**70% - 100%**	**10% - 100%**	**25% - 100%**	**50% - 100%**	**75% - 100%**
Test Statistic Sign Test		0.0000	0.0267	0.0000	0.0000	0.0000	0.0002	0.0000
		Ha	Ha	Ha	Ha	Ha	Ha	Ha
Count #1s	**ES**	11	7	12	11	11	10	12
	EVM	5	9	4	5	5	6	4

Hypothesis Test: Sign Test at 0.05 level of significance.
Ho: The aggregate of EVM forecasts is better / the null hypothesis
Ha: ES forecast is better / the alternate hypothesis

Summary

- Four traditional EVM forecasting methods were examined and compared to the ES technique
- Data from 16 projects was used to examine the performance of the 5 forecasting methods
- Seven ranges of percent complete were applied to isolate forecasting characteristics or tendencies
- The standard deviation from the actual final duration was used to evaluate forecasting performance

Summary

- Forecasting performance for each project was ranked from best to worst for the seven ranges of project completion
- The weighted averages of the rankings were used to evaluate goodness of performance
- Hypothesis testing of the best forecasts for each completion range was evaluated

Conclusions

- The weighted average of rankings indicate ES is a better predictor of final duration than any of the EVM methods
  - The PVav method showed to be close, but slightly worse than the ES technique for the 40% - 70% project completion range
- The hypothesis testing of best forecast yielded identical results to the weighted rankings

For every range of data grouping the ES forecast is identified as the better predictor of final duration

Acknowledgement

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  - Dr. Ofer Zwikael

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  - Kym Henderson

    IT Project Manager

    Sydney, AU

References

- "Prediction of Project Outcome: The Application of Statistical Methods to Earned Value Management and Earned Schedule Performance Indexes," *International Journal Of Project Management*, May 2009 Vol 27: 400-407 [Lipke, Zwikael, Anbari, Henderson]
- "Statistical Methods Applied to EVM …the next frontier," *CrossTalk*, June 2006: 20-23 [Lipke]
- "A Case Study of Earned Schedule to do Predictions," *The Measurable News*, Winter 2007-2008: 16-18 [Hecht]
- "Measuring the Accuracy of Earned Value/Earned Schedule Forecasting Predictors," *The Measurable News*, Winter 2007-2008: 26-30 [Vanhoucke & Vandevoorde]
- "A Simulation and Evaluation of Earned Value Metrics to Forecast Project Duration," *Journal of Operations Research Society*, October 2007, Vol 58: 1361-1374 [Vanhoucke & Vandevoorde]
- Earned Schedule Website: www.earnedschedule.com