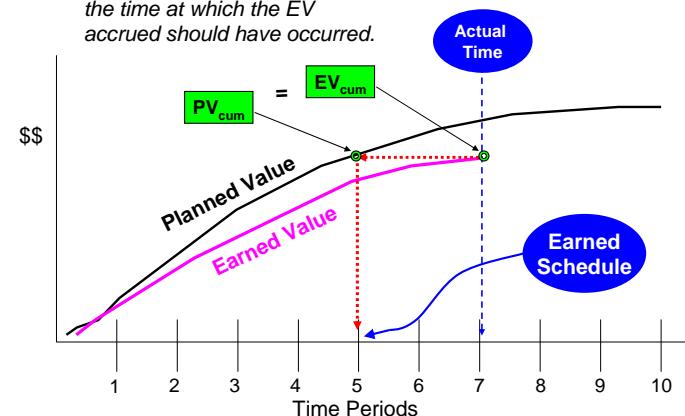


Advancing Project Duration Forecasting



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





Abstract

Project duration forecasting has been enhanced with the introduction and application of the techniques derived from Earned Schedule (ES). The computed forecast results from ES have been shown to be better than any other EVM-based method using both real and simulated performance data. However, research has shown that as the topology of the network schedule becomes more parallel, the accuracy of the ES forecast worsens. This presentation examines a possible approach for overcoming the dilemma to further improve the effectiveness of ES forecasting.



Overview

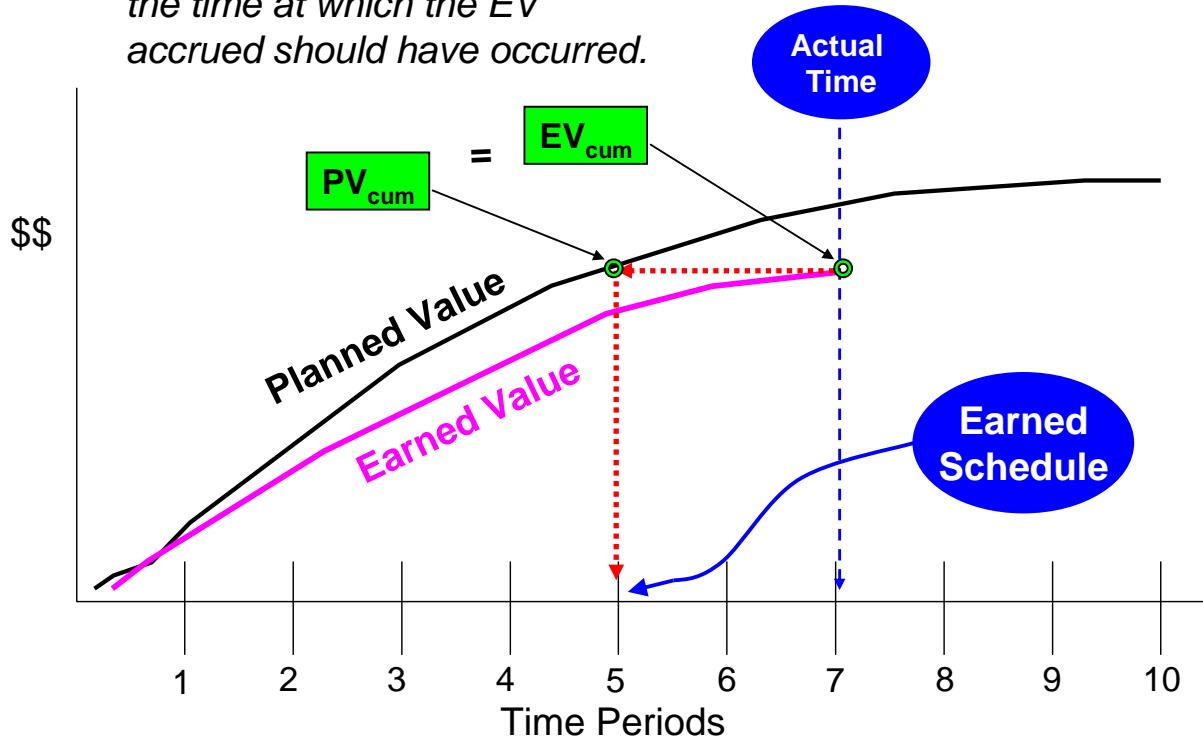
- Introduction
- Theory
- Methodology
- Project Data
- Analysis
- Results
- Other Examples
- Summary
- Final Thoughts



Introduction

- ES introduced in 2003

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





Introduction

- $ES = C + I$
where C is number of periodic time units of the
PMB for which $EV \geq PV_C$
and $I = [(EV - PV_C) / (PV_{C+1} - PV_C)] * 1$ period
- $SV(t) = ES - AT$
- $SPI(t) = ES / AT$
- $IEAC(t) = PD / SPI(t)$



Introduction

- The forecasting formula $IEAC(t) = PD / SPI(t)$ has proven to be reasonably good
 - Kym Henderson (real data) – 2004
 - Vanhoucke & Vandevoorde (simulation) – 2007
 - Lipke (EVM conversion) - 2008
- Recent research indicates ES forecasting more reliable for serial schedules and less so for parallel (Vanhoucke 2009)
- Recommended solution – combining two techniques – ES & SRA (Vanhoucke 2012)



Introduction

- Is there another approach which provides reliable forecasting for parallel topology schedule networks?
...If YES, then project control process may be improved and simplified
- The idea for examination is
... Using ES methods, does the longest duration forecast from the various serial paths to completion provide better, more reliable, information?



Theory

- Forecasts from serial schedules have been shown to be most reliable ...thus, the possible serial paths to completion of the network are identified for forecasting
- The longest forecast determined from the various paths at each performance period converges to the actual final duration with less variation than any other path
- If true, it follows that the set of longest forecasts resolves the parallel topology issue of ES forecasting applied to the total project



Theory

- From the beginnings of ES there has been a question of whether the project duration forecast is the “lower bound”
 - Logically, when $\text{IEAC}(t)_{LP} > \text{IEAC}(t)$, it is reasonable for $\text{IEAC}(t)$ to be considered the lower bound
 - The condition $\text{IEAC}(t)_{LP} > \text{IEAC}(t)$ must be reliable and necessary for designating the lower bound

$\text{IEAC}(t)_{LP}$ = Longest Path, $\text{IEAC}(t)$ = Total Project



Methodology

- Using notional data, duration forecasts are computed for the total project and the various serial paths to completion
- The longest path and total project forecasts are compared to determine the validity of the following statements
 - 1) The forecasts using the current LP are improved from those for the total project
 - 2) When $IEAC(t)_{LP} > IEAC(t)$, the total project forecast may be considered the “lower bound”
 - 3) The set of LP forecasts overcomes the negative effect of parallel schedule topology



Methodology

- To perform the calculations the ES Calculator (special cases) is needed
 - The ES method for CP forecasting is used for each of the possible paths to completion (Lipke, 2006)
 - The serial paths to completion begin at various times during project execution ...there will be EV data voids until execution begins
 - The calculator takes into account the periods within the paths during which no work is planned along with the execution voids (Lipke, 2011)

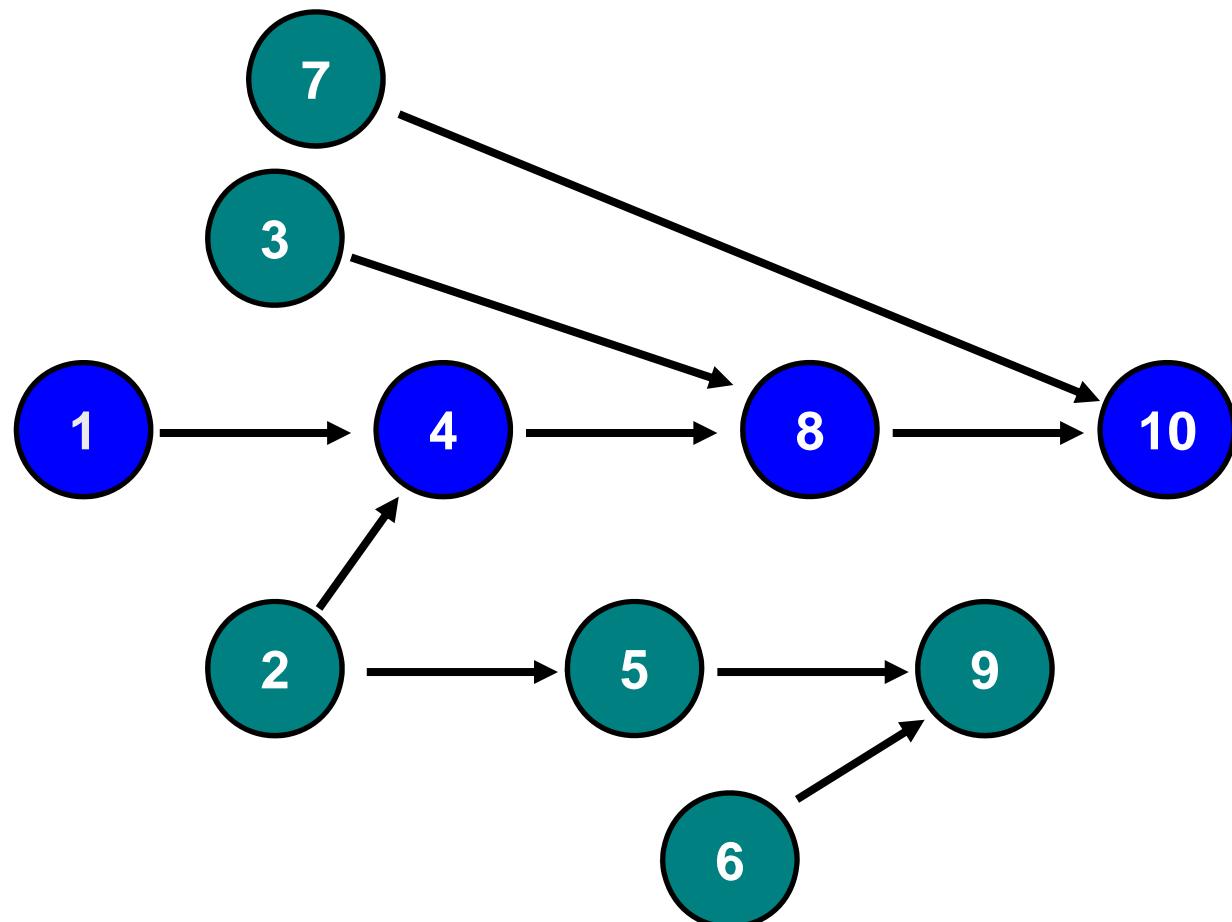


Project Plan Data

- Notional project has 10 tasks planned for completion in 10 periods with BAC = 185
- Critical Path is 1-4-8-10
- Six serial paths are identified
 - 1) 1-4-8-10, $BAC_1 = 55$
 - 2) 2-4-8-10, $BAC_2 = 50$
 - 3) 2-5-9, $BAC_3 = 40$
 - 4) 3-8-10, $BAC_4 = 60$
 - 5) 7-10, $BAC_5 = 60$
 - 6) 6-9, $BAC_6 = 25$



Project Schedule Paths





Notional Performance Data

Performance Path	Period	1	2	3	4	5	6	7	8	9	10	11	12
1-4-8-10	PVp	5	5	5	5	5	5	10	5	5	5		
	EVp	XX	4	8	10	3	0	12	8	0	10		
	PVc	5	10	15	20	25	30	40	45	50	55		
	EVc	XX	4	12	22	25	25	37	45	45	55		
2-4-8-10	PVp	XX	XX	10	5	5	5	10	5	5	5		
	EVp	XX	XX	3	11	6	0	12	8	0	10		
	PVc	XX	XX	10	15	20	25	35	40	45	50		
	EVc	XX	XX	3	14	20	20	32	40	40	50		
2-5-9	PVp	XX	XX	10	5	5	5	5	5	5			
	EVp	XX	XX	XX	12	6	5	2	0	4	5	3	3
	PVc	XX	XX	10	15	20	25	30	35	40			
	EVc	XX	XX	XX	12	18	23	25	25	29	34	37	40
3-8-10	PVp	XX	XX	10	10	10	5	10	5	5	5		
	EVp	XX	XX	8	13	9	0	12	8	0	10		
	PVc	XX	XX	10	20	30	35	45	50	55	60		
	EVc	XX	XX	8	21	30	30	42	50	50	60		
7-10	PVp	XX	XX	10	10	10	10	10	XX	5	5		
	EVp	XX	XX	XX	8	9	7	13	8	5	10		
	PVc	XX	XX	10	20	30	40	50	XX	55	60		
	EVc	XX	XX	XX	8	17	24	37	45	50	60		
6-9	PVp	XX	XX	XX	XX	5	5	5	5	5			
	EVp	XX	XX	XX	XX	XX	6	4	0	4	5	3	3
	PVc	XX	XX	XX	XX	5	10	15	20	25			
	EVc	XX	XX	XX	XX	XX	6	10	10	14	19	22	25
Total Project	PVp	5	5	35	30	35	25	25	10	10	5		
	EVp	XX	4	16	43	27	18	31	16	9	15	3	3
	PVc	5	10	45	75	110	135	160	170	180	185		
	EVc	XX	4	20	63	90	108	139	155	164	179	182	185



Analysis

- Execution of the various tasks does not necessarily coincide with the plan ...voids are seen in the EV and PV data
- The project did not complete on the Critical Path
- Two paths completed two periods past the planned duration of 10 periods, 2-5-9 and 6-9



Results

Performance Path	***** Period *****											
	1	2	3	4	5	6	7	8	9	10	11	12
1-4-8-10	13.50	13.50	9.33	7.82	9.00	11.00	9.96	9.75	11.00	10.00		
2-4-8-10			28.67	10.89	10.00	12.67	10.51	10.00	11.33	10.00		
2-5-9				8.00	8.38	8.83	10.00	11.75	11.75	11.45	11.75	12.00
3-8-10			12.00	9.62	10.00	12.67	10.51	10.00	11.33	10.00		
7-10				12.75	12.24	12.75	11.57	10.78	11.40	10.00		
6-9						9.17	10.00	12.50	12.14	11.58	11.82	12.00
Total Project		13.50	9.75	9.33	10.03	11.12	10.74	11.29	11.81	11.11	11.64	12.00

- The forecasts are shown in the table with the longest path identified by the lime color
- The longest path changes during execution
- The project finished late $\rightarrow \text{IEAC}(t)_{LP} \geq \text{IEAC}(t)$ at every period
- Both $\text{IEAC}(t)_{LP}$ & $\text{IEAC}(t)$ converge to the actual final duration, 12 periods



Results

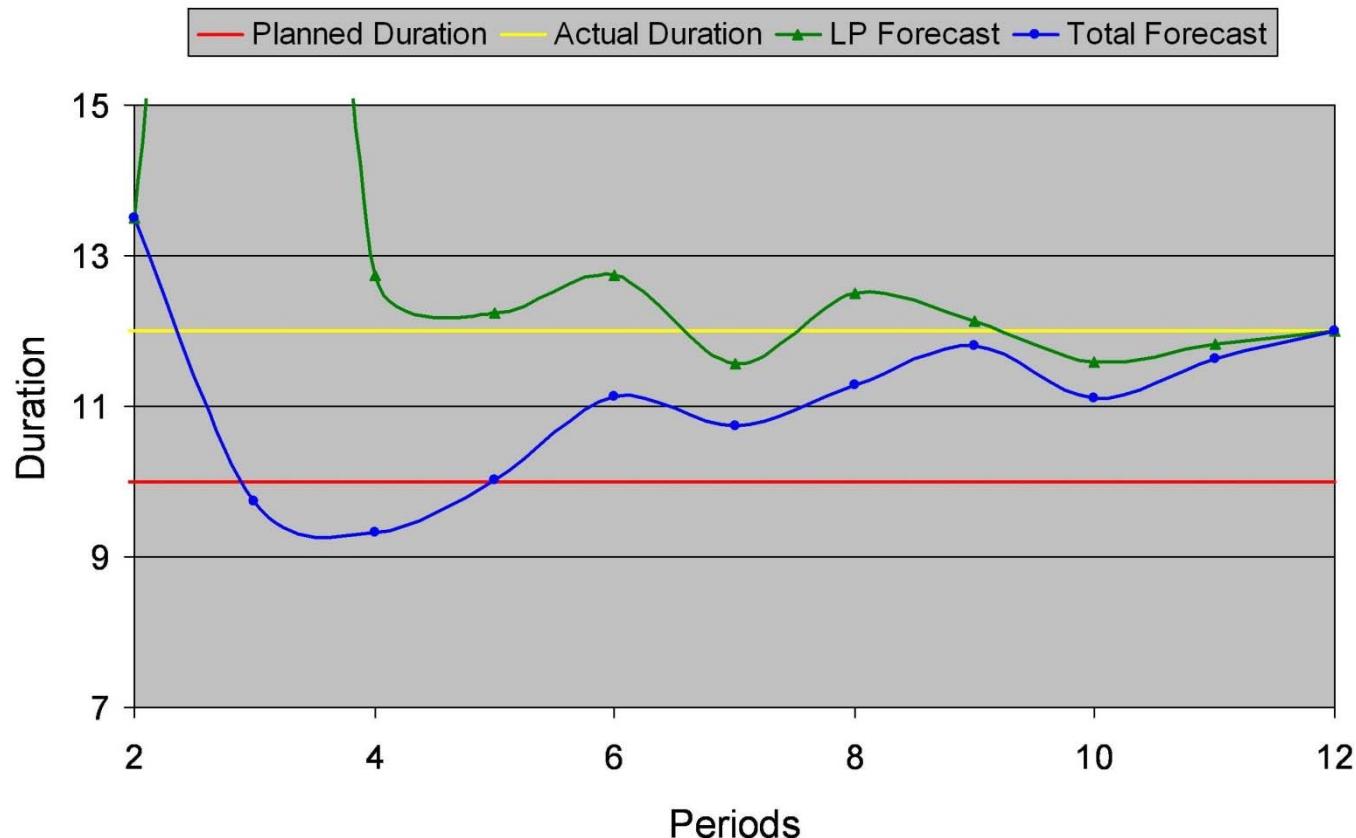
Period	1	2	3	4	5	6	7	8	9	10	11	12
Longest Path		1.50	11.83	0.43	0.39	0.49	0.48	0.48	0.45	0.45	0.43	0.41
Total Project		1.50	1.91	1.54	1.66	1.53	1.49	1.41	1.32	1.28	1.22	1.16

Omitted periods 2 & 3 in Std Dev calculations

- Variation of the forecasts from the final duration are compared in the table
- For periods 4 through 12 the LP forecast has less variation than the total project
- Both forecasts indicate convergence with variation decreasing as project moves to completion



Results



- Convergence and forecasting characteristics are readily seen from graph – LP forecast is more accurate and less variable



Other Examples

- Serial
- Parallel
- Serial ➔ Parallel



Example Serial

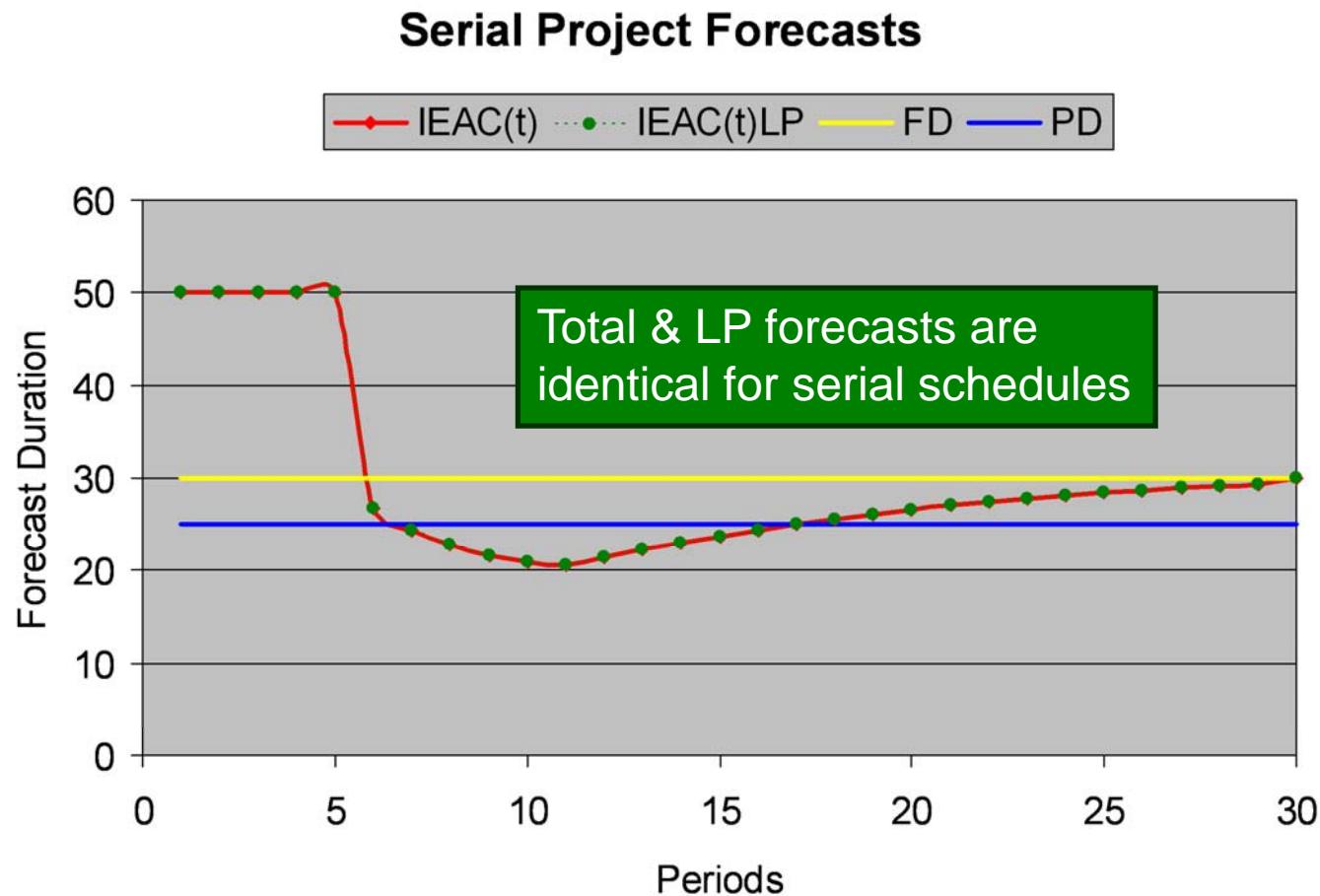
Concurrency!!

Serial Project																
	Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Task 1	PV	2	4	6	8	10										
	EV	1	2	3	4	5	6	7	8	9	10					
Task 2	PV						5	10	15	20	25	30	35	40	45	50
	EV						7	14	21	28	35	42	45	48	51	54
Task 3	PV															
	EV															
Total	PV	2	4	6	8	10	15	20	25	30	35	40	45	50	55	60
	EV	1	2	3	4	5	13	21	29	37	45	52	55	58	61	64
Period																
Task 1	PV															
	EV															
Task 2	PV	55	60	65	70	75										
	EV	57	60	63	66	69	72	75								
Task 3	PV						3	6	9	12	15					
	EV								2	4	6	8	10	12	14	15
Total	PV	65	70	75	80	85	88	91	94	97	100					
	EV	67	70	73	76	79	82	85	87	89	91	93	95	97	99	100

- Serial project sequence is 1-2-3, planned to complete in 25 periods ...Task1 completes 5 periods late; Task 2 begins as planned and completes 2 periods late; Task 3 begins when 2 ends and finishes 5 periods late



Example Serial





Example Parallel

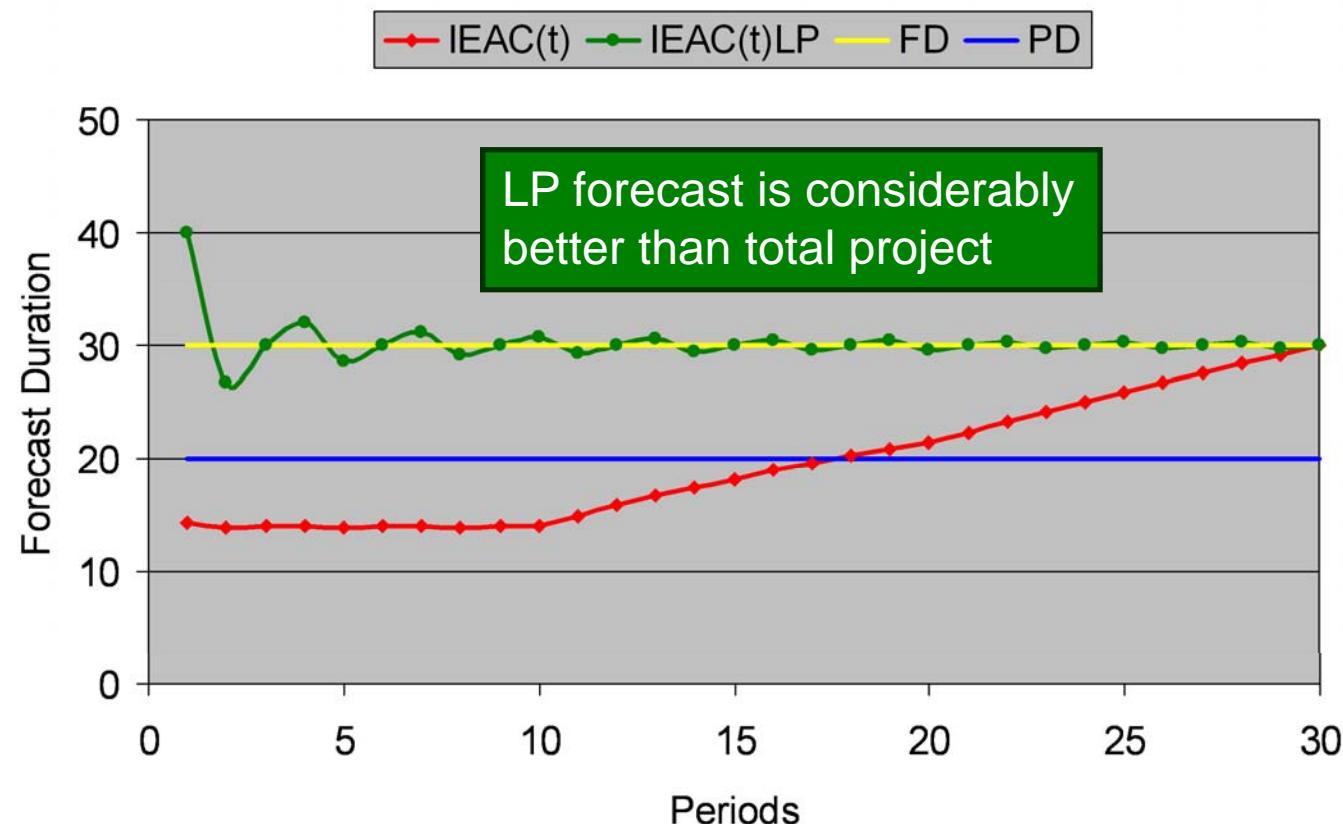
Parallel Project																
	Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Task 1	PV	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	EV	10	20	30	40	50	60	70	80	90	100					
Task 2	PV	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
	EV	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
Task 3	PV	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	EV	1	3	4	5	7	8	9	11	12	13	15	16	17	19	20
Total	PV	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
	EV	14	29	43	57	72	86	100	115	129	143	148	152	156	161	165
	Period	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Task 1	PV	80	85	90	95	100										
	EV															
Task 2	PV	48	51	54	57	60										
	EV	48	51	54	57	60										
Task 3	PV	32	34	36	38	40										
	EV	21	23	24	25	27	28	29	31	32	33	35	36	37	39	40
Total	PV	160	170	180	190	200										
	EV	169	174	178	182	187	188	189	191	192	193	195	196	197	199	200

- Project has 3 parallel tasks, all planned to begin and complete simultaneously in 20 periods
- Task 1 completes in 10 periods; Task 2 executes exactly as planned; and Task 3 completes 10 periods late



Example Parallel

Parallel Project Forecasts





Example Serial-Parallel

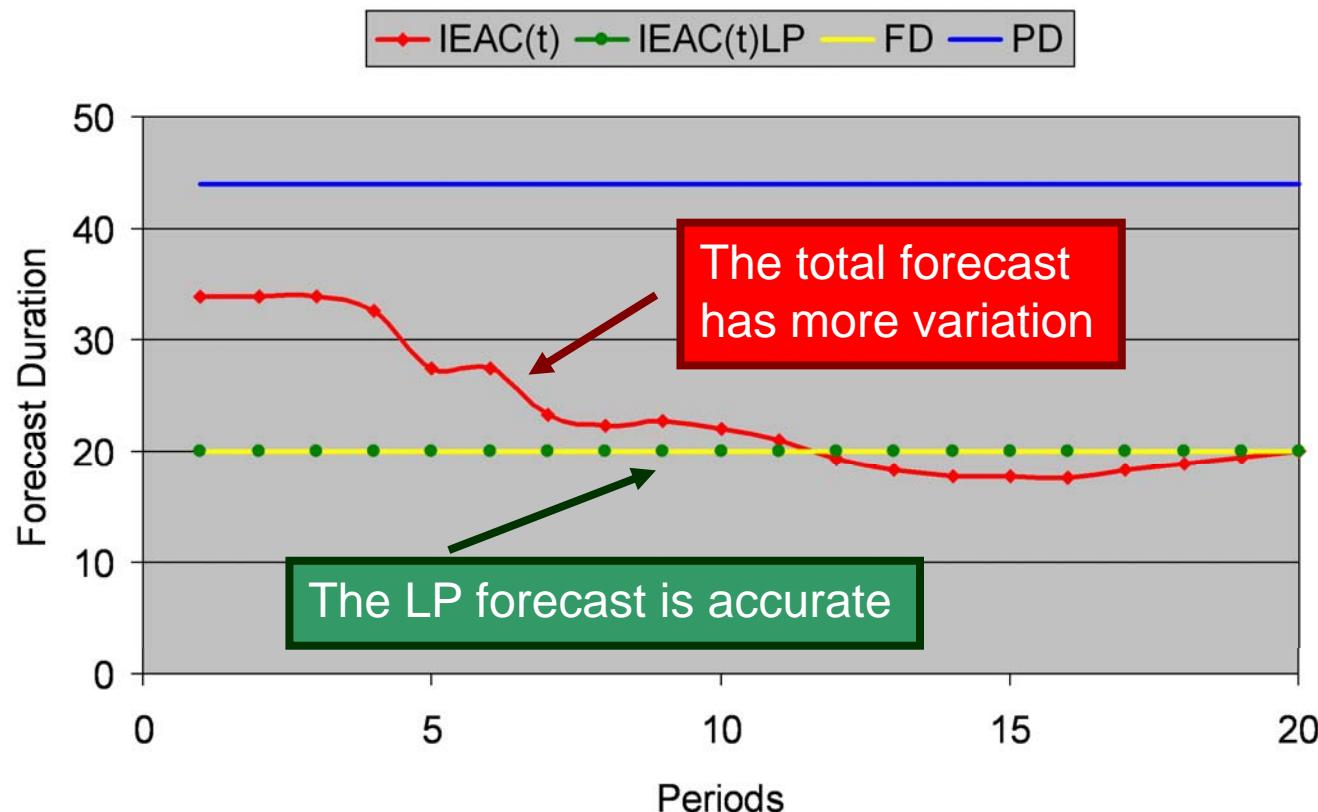
		Serial-Parallel Project																							
		Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Task 1	PV	5	15	25	35	45	50	55	60	65	70	75	80	85	90	95	100								
	EV	5	15	25	35	45	50	55	60	65	70	75	80	85	90	95	100								
Task 2	PV																								
	EV	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60				
Task 3	PV																					10	15	20	25
	EV											10	15	20	25	30	34	38	40				30	34	
Total	PV	5	15	25	35	45	50	55	60	65	70	75	80	85	90	95	100	110	115	120	125	130	134		
	EV	8	21	34	47	60	68	86	99	112	125	138	150	162	172	180	188	191	194	197	200				
		Period	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	
Task 1	PV																								
	EV																								
Task 2	PV				3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	
	EV																								
Task 3	PV	38	40																						
	EV																								
Total	PV	138	140	143	146	149	152	155	158	161	164	167	170	173	176	179	182	185	188	191	194	197	200		
	EV																								

- From the table, the project is planned to be executed serially, 1-3-2, finishing in 44 periods
- The project is executed concurrently, completing in only 20 periods



Example Serial-Parallel

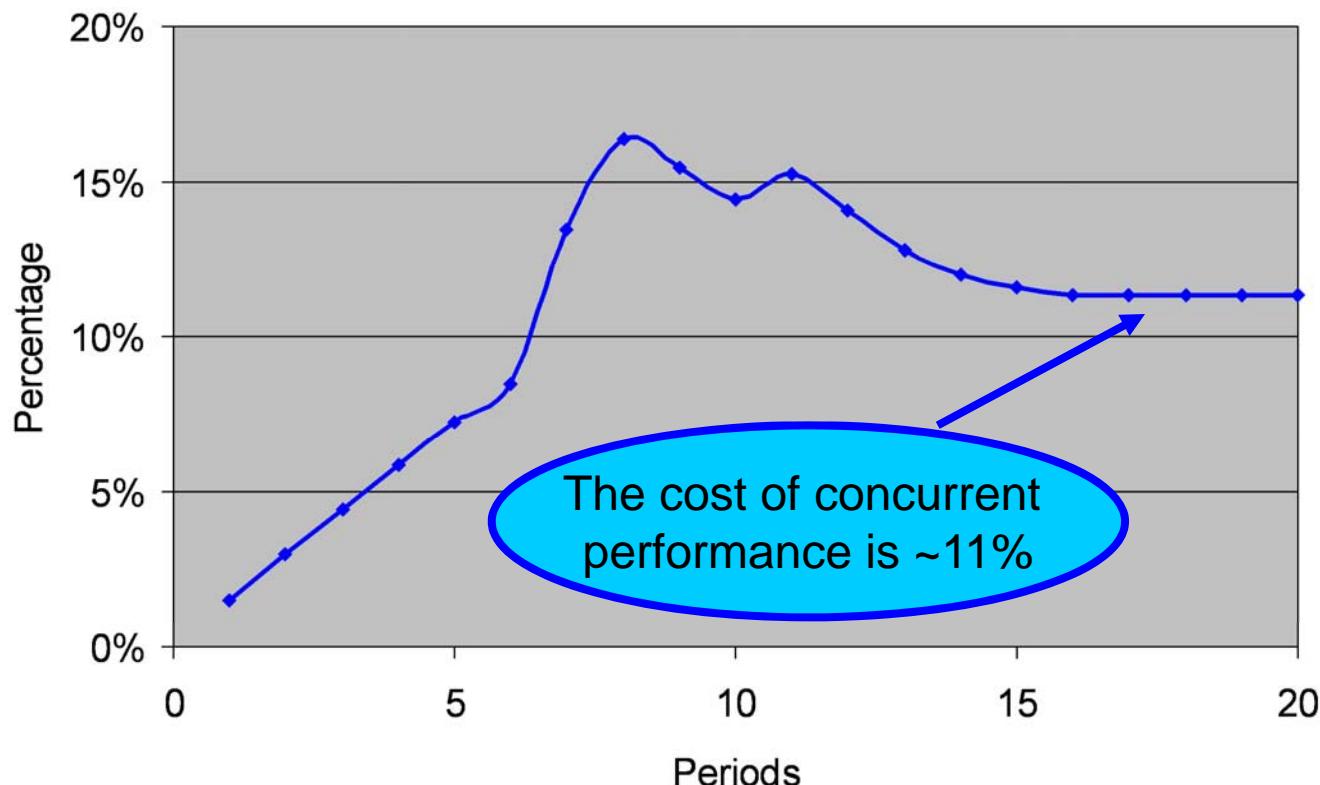
Serial-Parallel Project Forecasts





Example Serial-Parallel

Serial - Parallel Project Rework





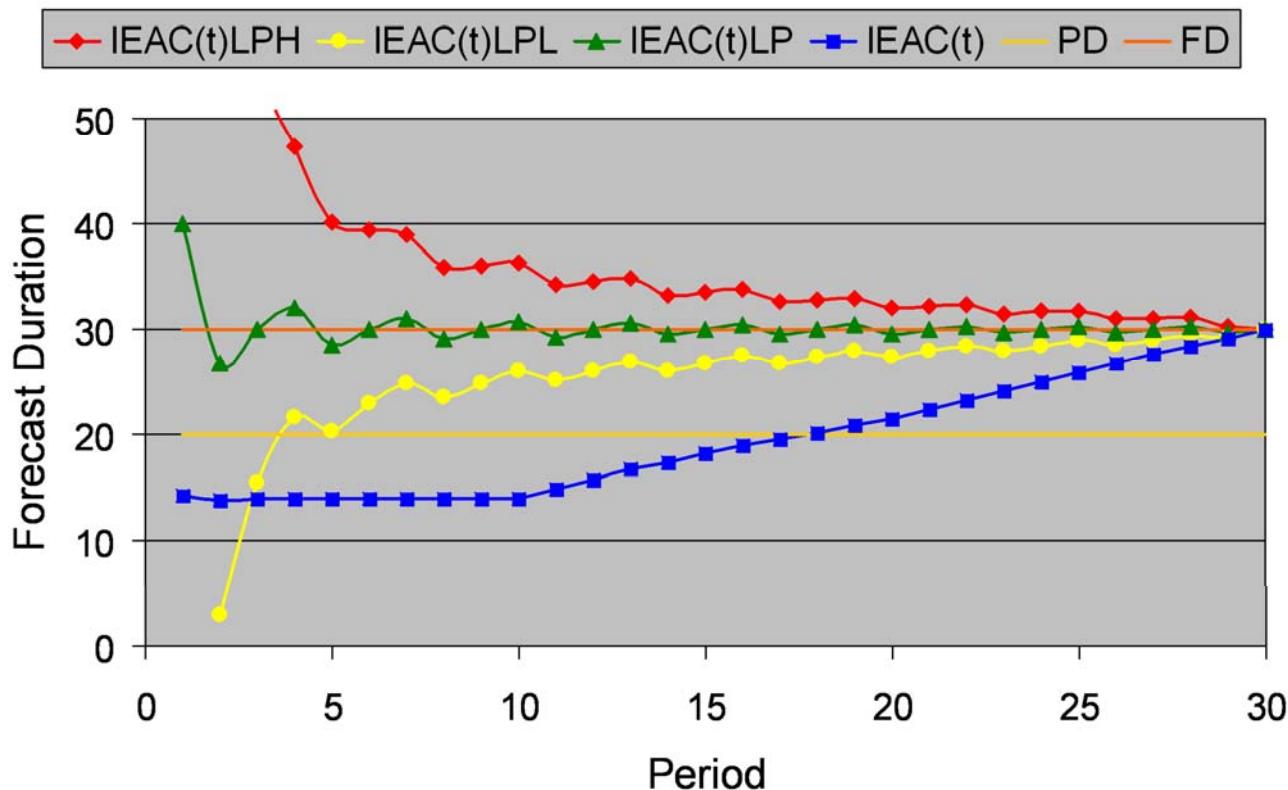
...And More

- Statistical Forecasting
- Prediction



Example Parallel

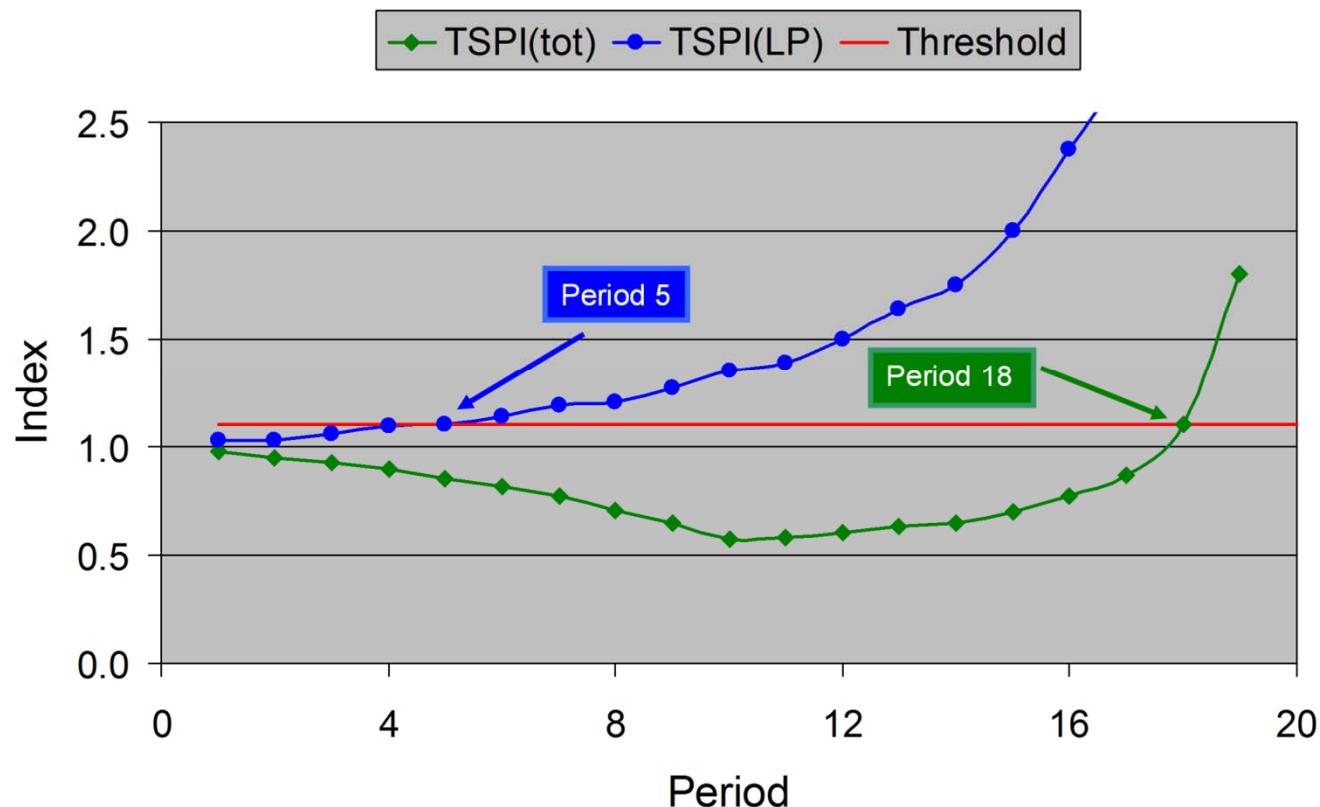
Statistical Forecasting - Longest Path





Example Parallel

Prediction Comparison





Summary

- Schedule topology affects the “goodness” of ES forecasting – as the schedule becomes more parallel the forecasting accuracy decreases
- The idea of “longest path” (LP) was proposed and tested with notional data
 - The LP forecast provided better results in every instance
 - It is reasonable to assume IEAC(t) is the lower bound when the LP forecast is consistently greater
 - The LP forecast appears to be a significant improvement – more testing is needed before declaring the method resolves the ES forecasting problem for parallel topology schedules



Summary

- Analysis findings from the Examples –
 - For completely serial schedules the LP and total project forecasts are identical
 - For completely parallel schedules, LP forecasting is significantly better than IEAC(t)
 - The serial schedule executed concurrently in complete agreement with the planned PV values
 - ❖ The total project forecast has more variation but eventually converged to FD
 - ❖ The LP forecast method selected the longest duration task yielding an accurate forecast



Summary

- Forcing concurrency is believed to have an associated risk
 - The induced rework from imposed concurrency was postulated as a way to evaluate the risk
 - Using ES methods for schedule adherence and rework forecasting the cost impact of concurrency is estimated to be ~11%



Summary

- Parallel Example - Statistical Forecasting
 - Ease of applying statistical forecasting
 - Clear demonstration of parallel schedule impact on forecast
 - ❖ $\text{IEAC}(t)_{LP} > \text{IEAC}(t)$ after period 3
- Parallel Example – Prediction Comparison
 - Recognition of threshold breach significantly earlier by TSPI_{LP}



Final Thoughts

- Longest path forecasting requires more testing and validation before it can be considered a viable method
- Those who have EV data and schedule information for their projects are invited to evaluate LP forecasting and publish their findings ...you will need the ES (special cases) calculator from the ES website
- For the purpose of creating common language, ES forecasting using LP ➔ *ES-LP*



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