Earned Schedule

Project Duration Forecasting Advancements

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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 Earned Value Management based method using both real and simulated performance data. Even so, research has shown that as the topology of the network schedule becomes more parallel, the accuracy of the ES forecast worsens. Recently, forecast accuracy improvement has been achieved for highly parallel type schedules with the method of Earned Schedule-Longest Path. This presentation proposes further advancement to the longest path approach through anomaly rejection and the application of simple statistical methods.

Objective

- Understand how ES is derived from EVM data, and its facility for schedule analysis & forecasting
- Know why Longest Path (LP) improves ES forecasting
- Learn how to identify LP forecast anomalies
- Understand and apply statistical forecasting
- Know how to use LP to make statistical forecasts

Overview

- Introduction
- Notional Data / Path Performance
- Longest Path Forecasting
- ES Requirement/ Anomaly Identification
- Improved ES-LP Forecasting
- Statistical Forecasting with improved ES-LP
- Wrap Up

Introduction

Earned Schedule

Introduction / Earned Schedule

- EVM schedule indicators fail for late performing projects
- Earned Schedule overcomes the problem and has been shown to be the best of all EVM-based methods for providing reliable management information – indicators & forecasts
- ES formulas - indicator & forecast
  - SPI(t) = ES / AT
  - IEAC(t) = PD / SPI(t)

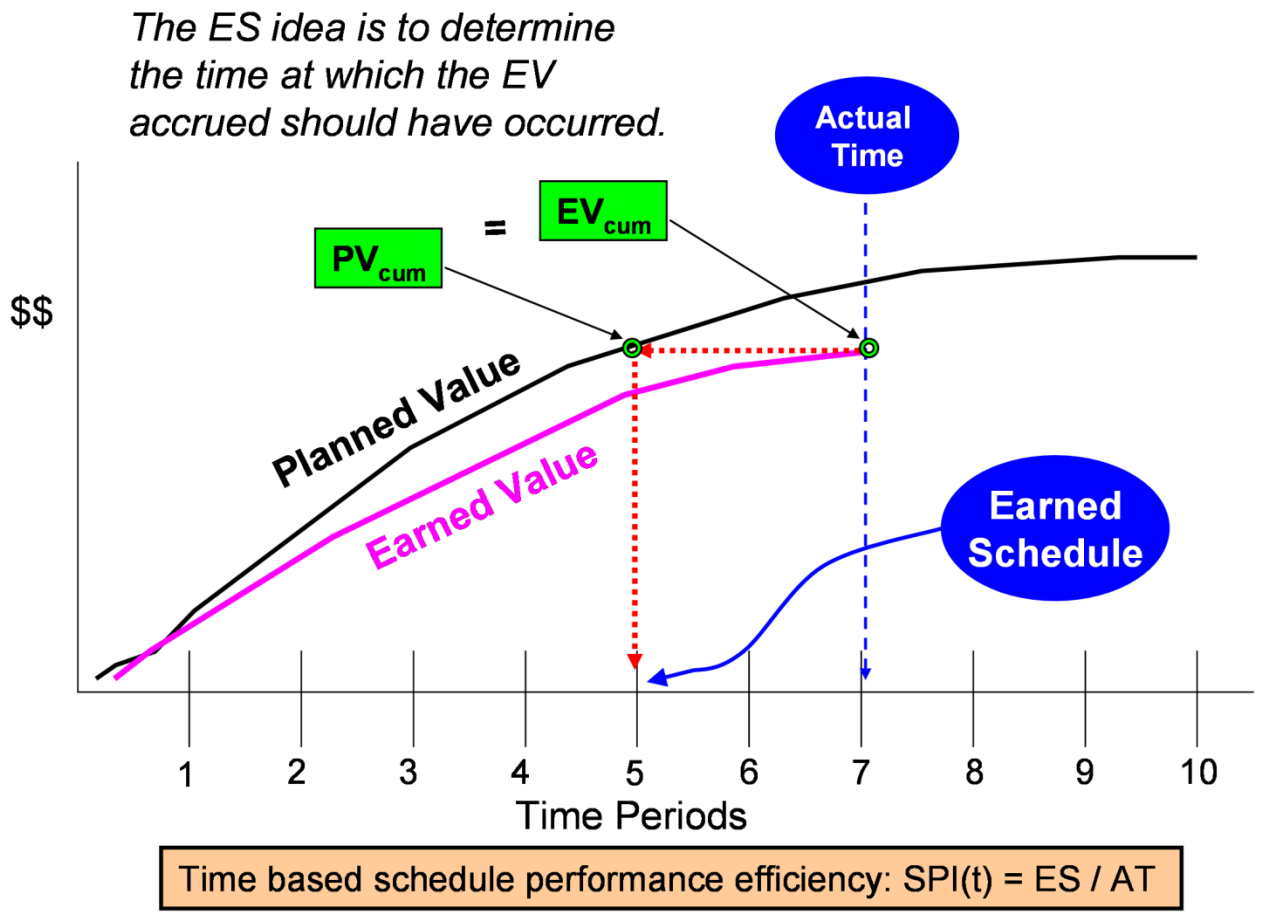
where AT = Actual Time – duration from start to now

SPI(t) = Schedule Performance Index (time-based)

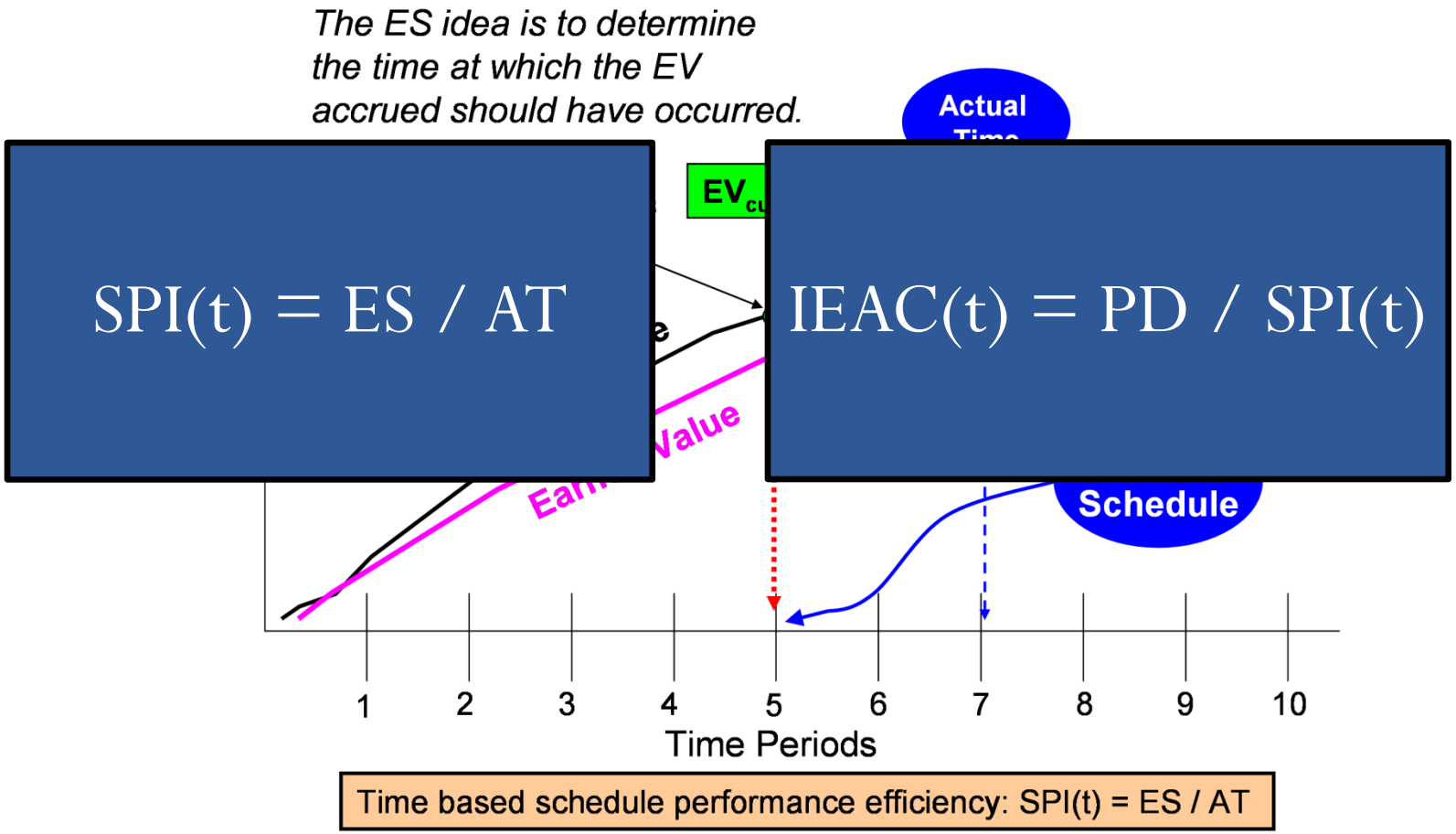
PD = Planned Duration

IEAC(t) = Independent Estimate at Completion (time-based)

Introduction / Earned Schedule



Introduction / Earned Schedule



Introduction / Earned Schedule

- Analysis Capabilities
  - Performance Indicators *(Variance, Efficiency)* – SV(t), SPI(t)
  - Forecasting *(Duration, Completion Date)* – IEAC(t)
  - Prediction *(Likely, Recover, Unlikely)* – TSPI
  - Critical Path Analysis *(Compare CP vs Project)*
  - Schedule Adherence *(portion of EV matching PV)* – p-factor
    - Identification of Constraints/Impediments & Rework
    - Rework Forecast & Schedule Adherence Index
    - Effective EV *(portion of EV not associated with rework)*
  - Analysis of discontinuous performance *(stop work & down time)*
  - Longest Path *(improved forecasting)*

Introduction/ ES Affirmation

- Simple theory
- Initial prototype
- Independent confirmation
  - Trials
  - Testing
- Global Use
- EVM Tools
- Educators/Researchers
- Application Standards
- Awards

Introduction/ ES Affirmation

- Simple theory
- Initial prototype
- Independent confirmation
  - Trials

"The retrospective analysis of ES using my own EVM projects' data, … has confirmed with remarkable precision the accuracy of the ES concept and ES metrics …when compared to their historic EVM counterparts."

- Henderson (2003)

- Application Standards
- Awards

Introduction/ ES Affirmation

- Simple theory

> "The results reveal that the earned schedule method outperforms …all other forecasting methods."
>
> - Vanhoucke & Vandevoorde (2007)

  - Testing

> "This research finds Earned Schedule to be a more timely and accurate predictor than Earned Value Management."
>
> - Capt. Kevin Crumrine (2013)

- Application Standards
- Awards

Longest Path

Introduction / Longest Path

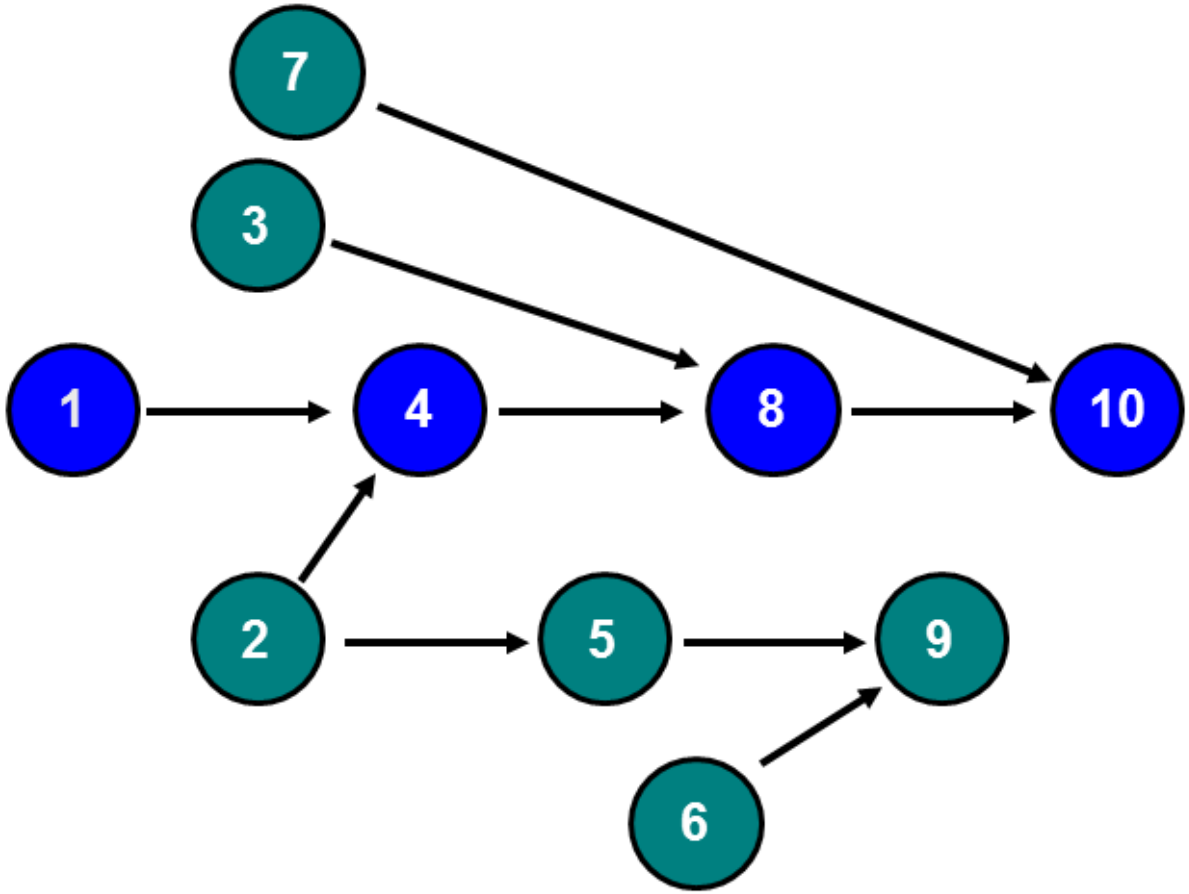
- Belgian researcher, Dr. Mario Vanhoucke, determined –

ES forecasting becomes less reliable as the topology of the schedule becomes increasingly parallel.

- Proposed solution –

Compute forecasts for all serial paths in the schedule. The longest duration forecast is taken to best represent the project.

Introduction / Longest Path



Statistical Forecasting

Introduction / Statistical Forecasting

- Most likely forecast: IEAC(t) = PD / SPI(t) …using the cumulative value of the index
- Confidence Limits are computed to determine the upper and lower forecast values …within which with 90% probability (for example) is the actual final duration
- Variation is required to make the calculation …i.e. the standard deviation
- Periodic values of SPI(t) are used to compute the standard deviation

Introduction / Statistical Forecasting

- $CL_{(+/-)} = \ln SPI(t)_c \pm Z \times \sigma_m \times AF$

where CL = Confidence Limit

$\ln SPI(t)_c$ = logarithm of the cumulative value of SPI(t)

Z = the prescribed Confidence Level (usually 90 percent)

$\sigma_m = \sigma / \sqrt{n}$, the standard deviation of the sample means

σ = the standard deviation for values of $\ln SPI(t)_p$

n = the number of periodic values

$AF = \sqrt{((PD - ES) / (PD - ES/n))}$, the adjustment for finite population

- $IEAC(t)_{(+/-)} = PD / e^{\wedge}CL_{(-/+)}$

where e = base number for natural logarithms

Application to Notional Data

- Notional Data
- Longest Path Forecast
- Graphical Comparison – LP vs Total Project
- Anomaly Recognition
- Improved Forecast
- Statistical Forecast from ES-LP
- Statistical Forecast Comparisons

Notional Data / Path Performance

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

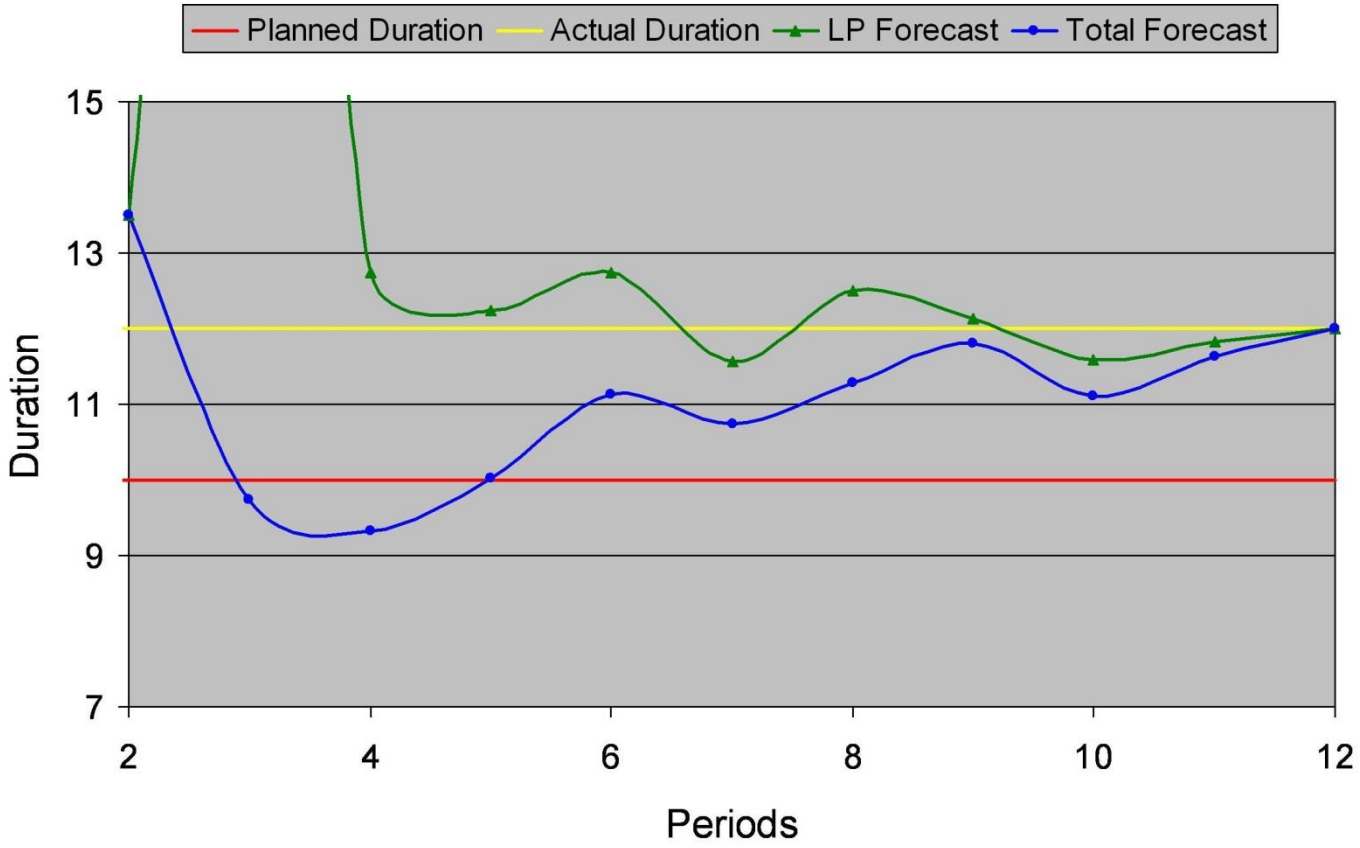
Longest Path Forecasting

- Total Project and Path forecasts in light-green
- Longest duration forecasts in lime-green

Performance Path	**** **** **** Period **** **** ****											
	1	2	3	4	5	6	7	8	9	10	11	12
1-4-8-10		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

Longest Path Forecasting

- Comparison of forecasts, Longest Path to Total Project



ES Requirement / Anomaly Identify

- Fundamental …when EV increases, ES must as well
- Verify for identified LP forecasts

$$ES(L) = PD \times AT \,/\, IEAC(t)_{LP}$$

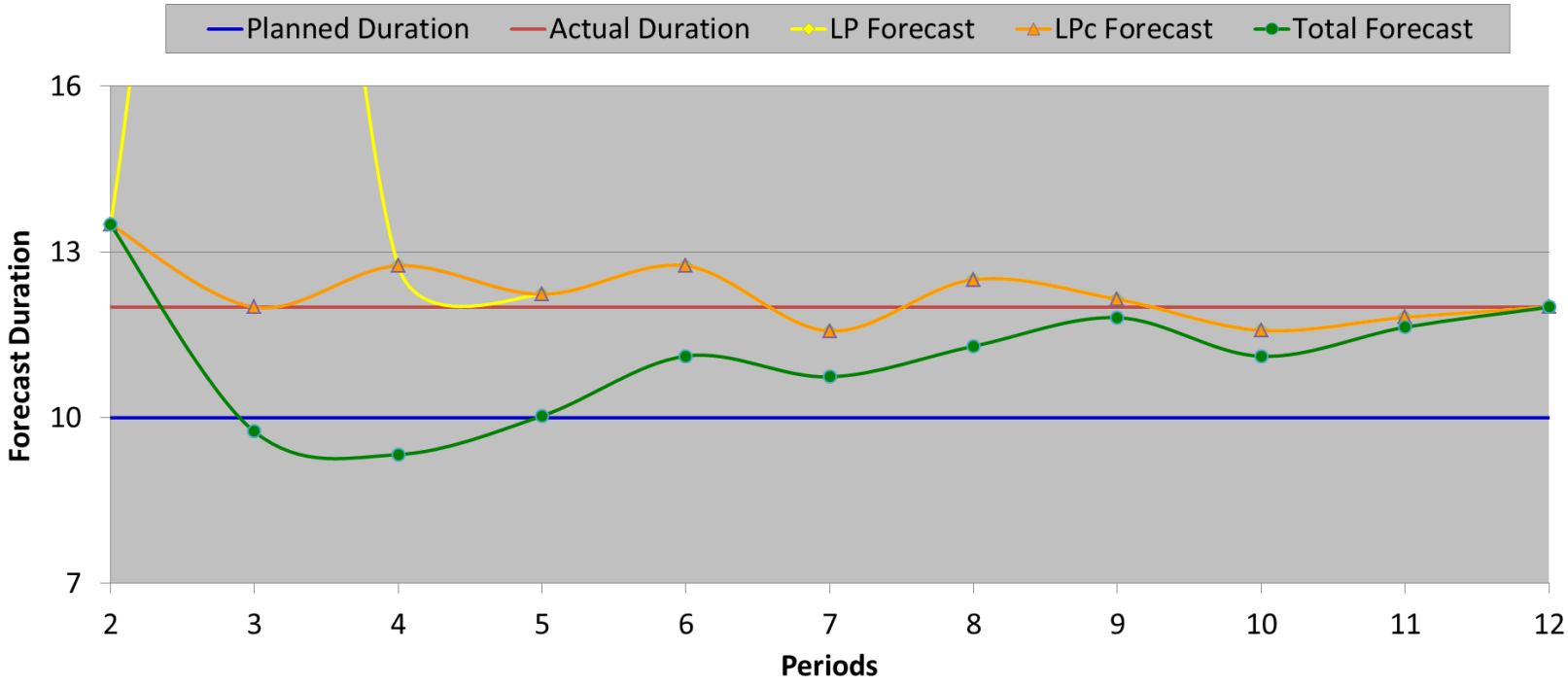
- Anomaly identified for period 3

Performance Path	**** **** **** ES(L) by Period **** **** ****											
	1	2	3	4	5	6	7	8	9	10	11	12
1-4-8-10		1.48	3.21	5.12	5.56	5.45	7.03	8.21	8.18	10.00		
2-4-8-10			1.05	3.67	5.00	4.74	6.66	8.00	7.94	10.00		
2-5-9				5.00	5.96	6.79	7.00	6.81	7.66	8.73	9.36	10.00
3-8-10			2.50	4.16	5.00	4.74	6.66	8.00	7.94	10.00		
7-10				3.14	4.09	4.71	6.05	7.42	7.89	10.00		
6-9						6.55	7.00	6.40	7.41	8.64	9.31	10.00
Total Project		1.48	3.08	4.29	4.98	5.40	6.52	7.08	7.62	9.00	9.45	10.00

Improved ES-LP Forecasting

- Selection of LP for a period is conditional:

Due to the requirement for ES(L) to increase, LP is chosen as the longest forecast having a positive change in ES(L).

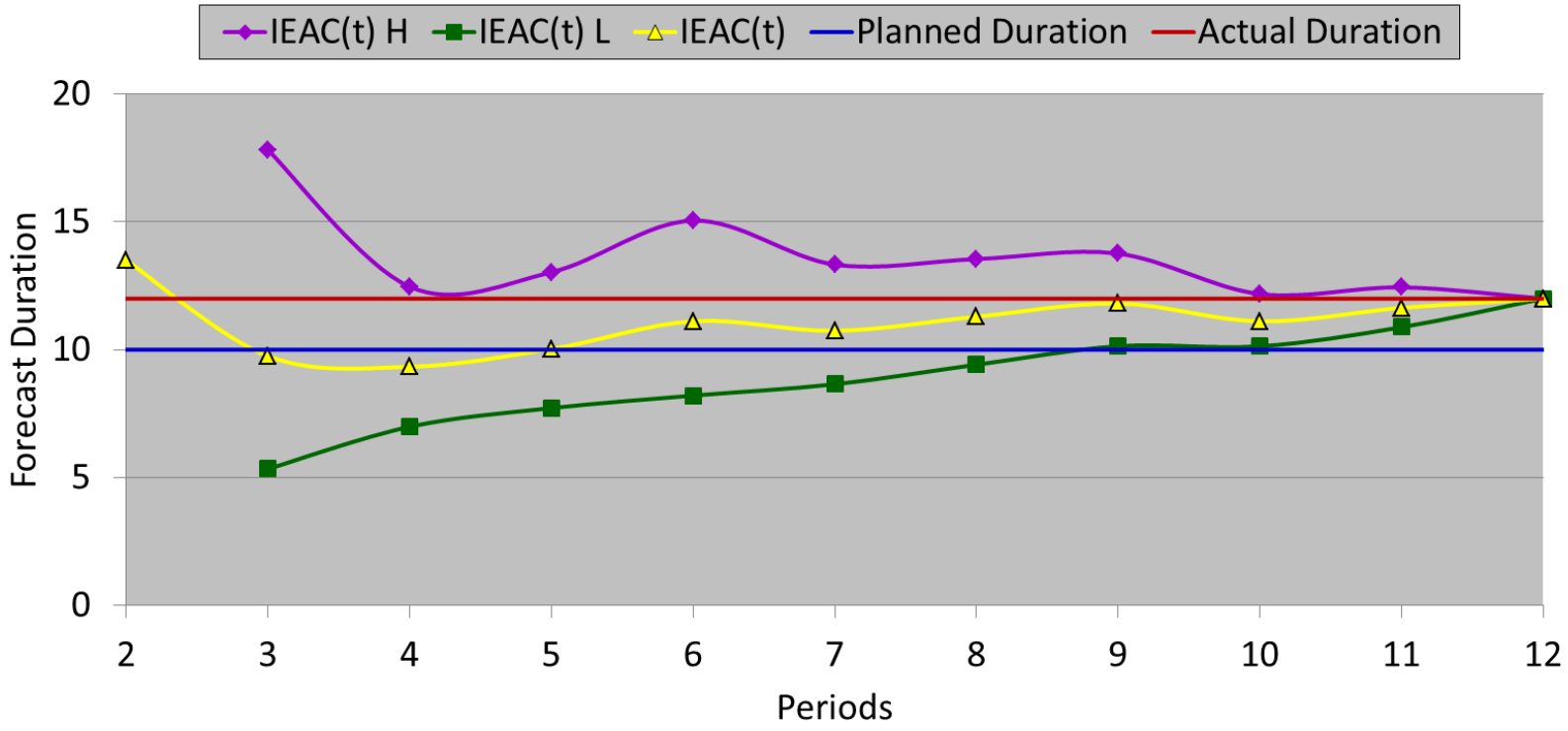


Statistical Forecasting

- Initially – not believed possible
- Even if possible – overly burdensome and complex
- Nevertheless, the promise of ES(L)-LP warrants the effort
- As discovered, implementation …IS SIMPLE
- Only requirement – ability to compute $SPI(t)_p$
- To obtain periodic SPI(t), all that is needed are periodic values of ES, regardless of their attribution …and thus
  - ES values from the total project will yield its set of statistical forecasts
  - ES(L) values provide associated Longest Path forecasts

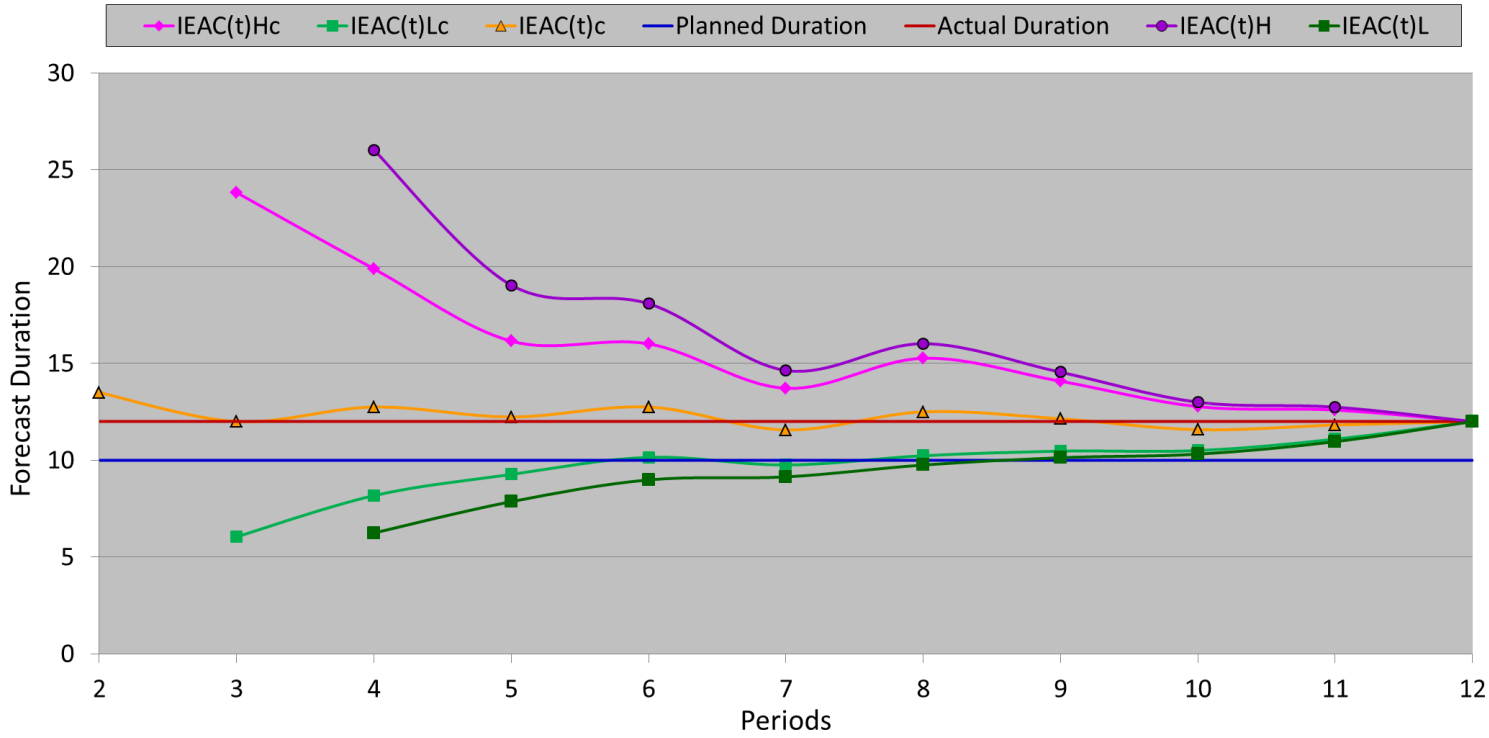
Statistical Forecasting

- Total Project statistical forecast



Statistical Forecasting

- ES(L)-LP and ES-LP statistical forecasts
  - More symmetrical than Total Project plots
  - Larger variation for ES-LP



Statistical Forecasting

- Put off by the extra effort? …*probably*
- Unproven method and extra effort …*into the waste basket*
- Both research and application results needed for verification
- With good results automated tools are created …drawbacks are removed
- For researchers and early adopters some assistance is offered by Excel files from ES website (www.earnedschedule.com)
  - ES Calculator vs1d …*down time & stop work conditions*
  - ES-LP Calculator v1c …*forecasts & ES(L)*
  - Statistical Forecasting Calculator v2c …*confidence limits, graphs*

Statistical Forecasting

- UK project analyst has applied ES-LP and reported good results
- Project Flight Deck incorporating ES-LP into their schedule analyzer tool
- PFD prototyping tool with two UK project performance analysts
- Assuming success …it is an easy extension to incorporate statistical forecasting
- Deemed useful …tool vendors incorporate and market

Wrap Up

- ES project duration forecasting has proven to be reliable
- ES forecasting becomes less reliable as topology of schedule becomes increasingly parallel
- Concept of LP proposed to overcome deficiency
- Selection of LP determined to be conditional
- ES(L) values utilized to compute $SPI(t)_p$,σ, and CLs
- Observed improvement with notional data
- Verification through research and application

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Thank You!!
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