# Speculations on Project Duration Forecasting

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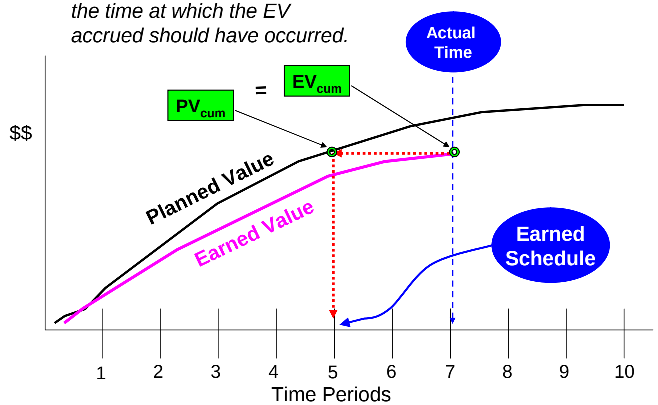
*The ES idea is to determine the time at which the EV accrued should have occurred.*



# 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.*

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# Overview

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

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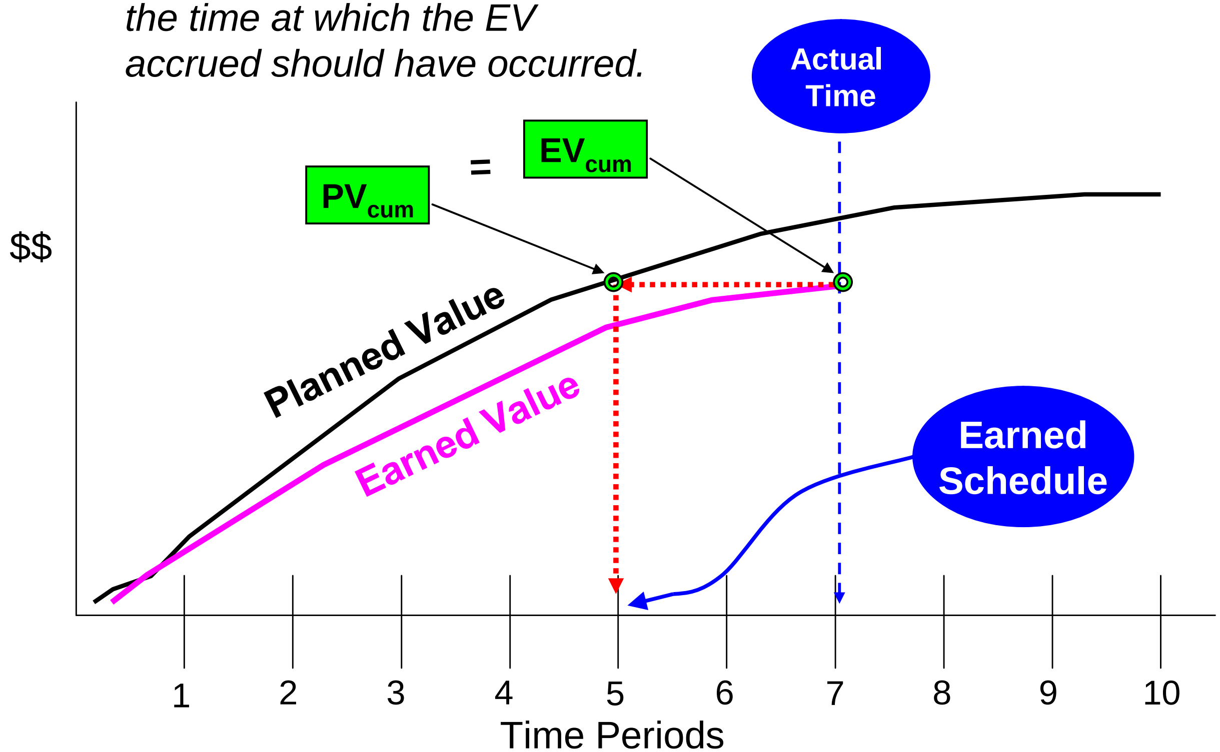
# Introduction

- 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

- $SV(t) = ES - AT$

- $SPI(t) = ES / AT$

- $IEAC(t) = PD / SPI(t)$

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# 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)

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# 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 $IEAC(t)_{LP} > IEAC(t)$, it is reasonable for IEAC(t) to be considered the lower bound
  - The condition $IEAC(t)_{LP} > IEAC(t)$ must be reliable and necessary for designating the lower bound

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$IEAC(t)_{LP}$ = Longest Path, 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

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# 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)

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# 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, $BAC_6 = 25$

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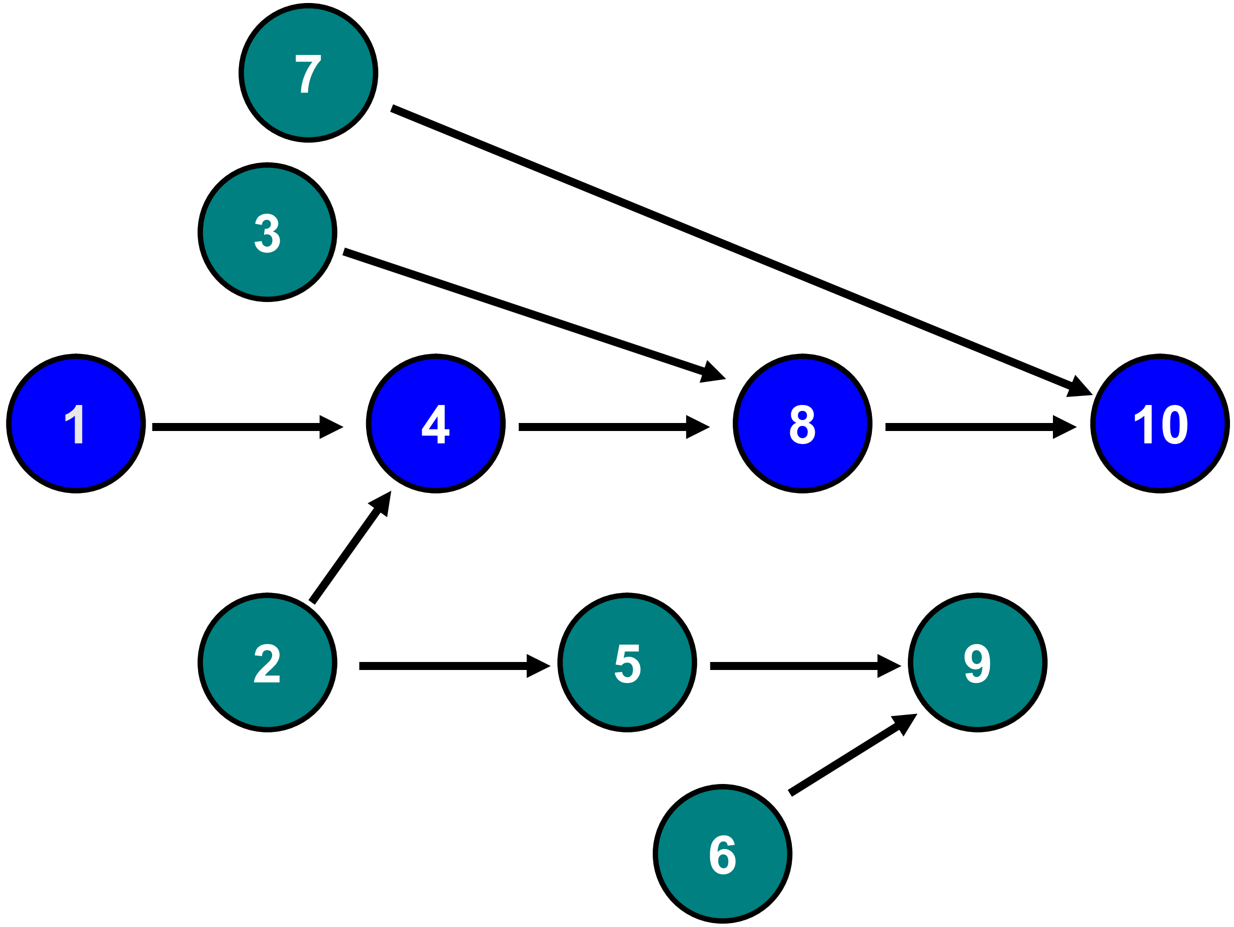
# Project Schedule Paths



# 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 |

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# 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

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# Results

| 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 |

- 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 ⇨ $IEAC(t)_{LP} \geq IEAC(t)$ at every period
- Both $IEAC(t)_{LP}$ & IEAC(t) converge to the actual final duration, 12 periods

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# 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

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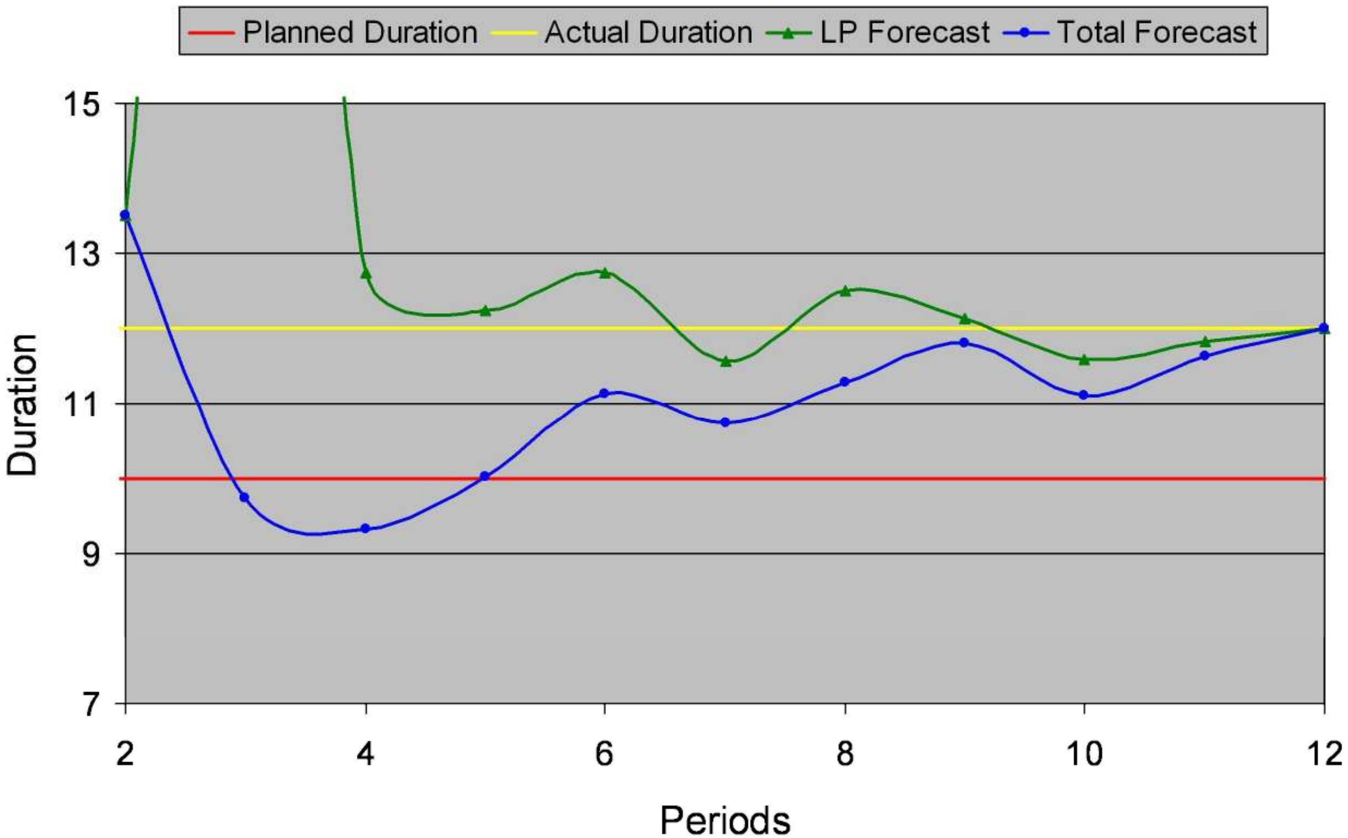
# Results




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

# Other Examples

- Serial
- Parallel
- Serial ⇨ Parallel

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# 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 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 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 |

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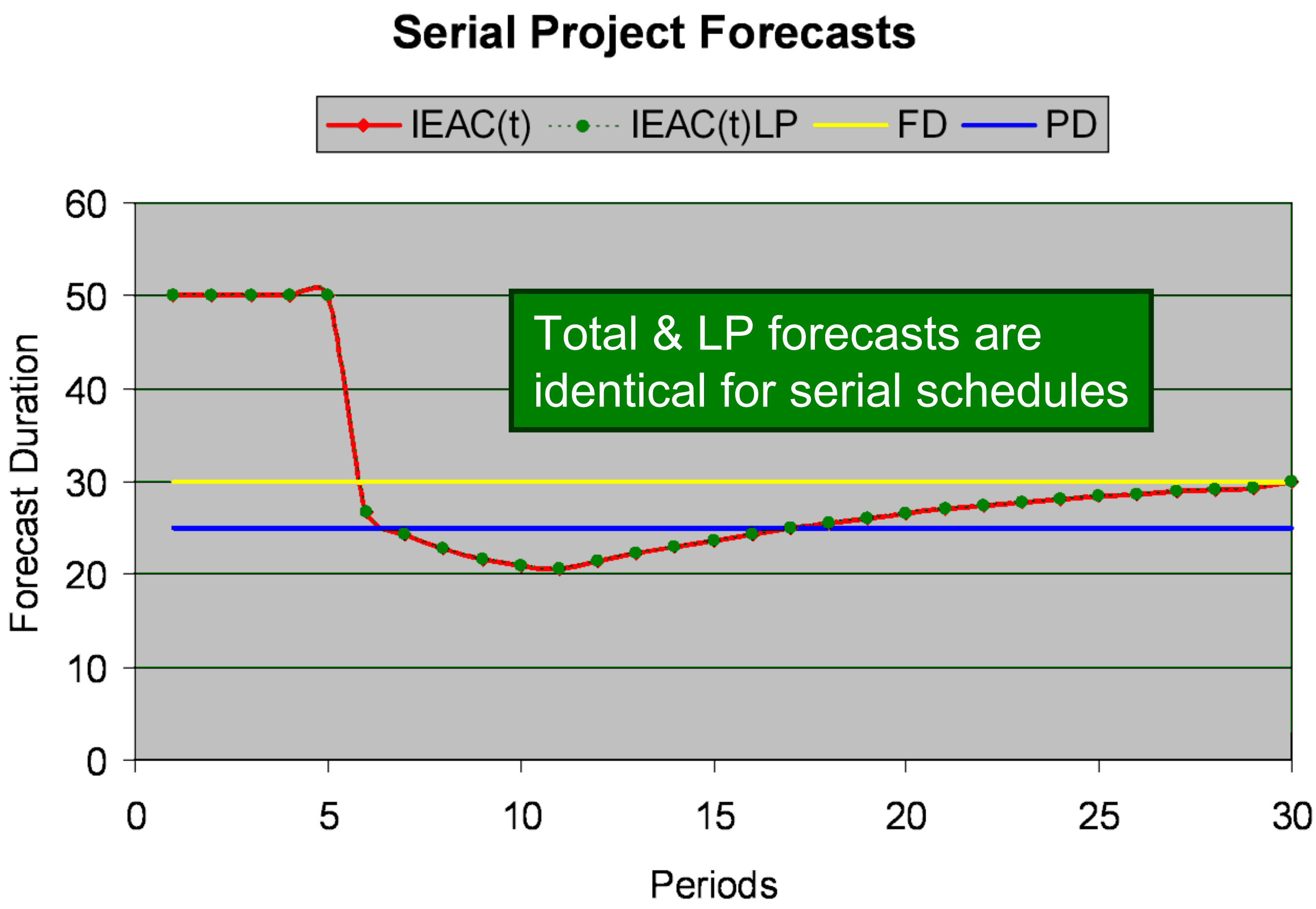
- Serial project sequence is 1-2-3, planned to complete in 25 periods …Task1 completes 5 periods late; Task 2 begins as planned and completes 2 periods late; Task 3 begins when 2 ends and finishes 5 periods late

# Example Serial



# Example Parallel

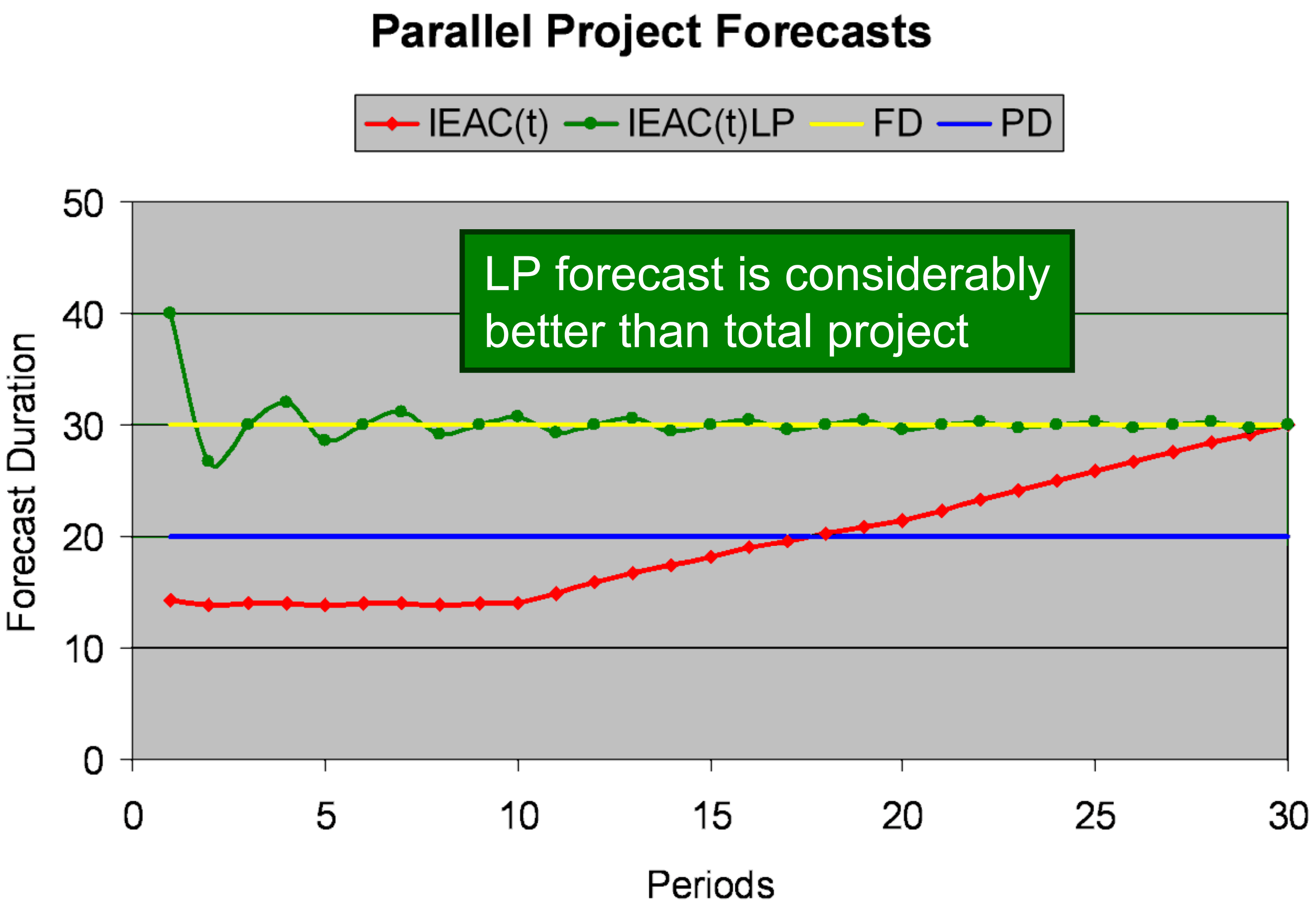
**Parallel Project**

| | 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



# 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 | 30 | 34 |
| | EV | | | | | | | 10 | 15 | 20 | 25 | 30 | 34 | 38 | 40 | | | | | | | | |
| 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 | | |

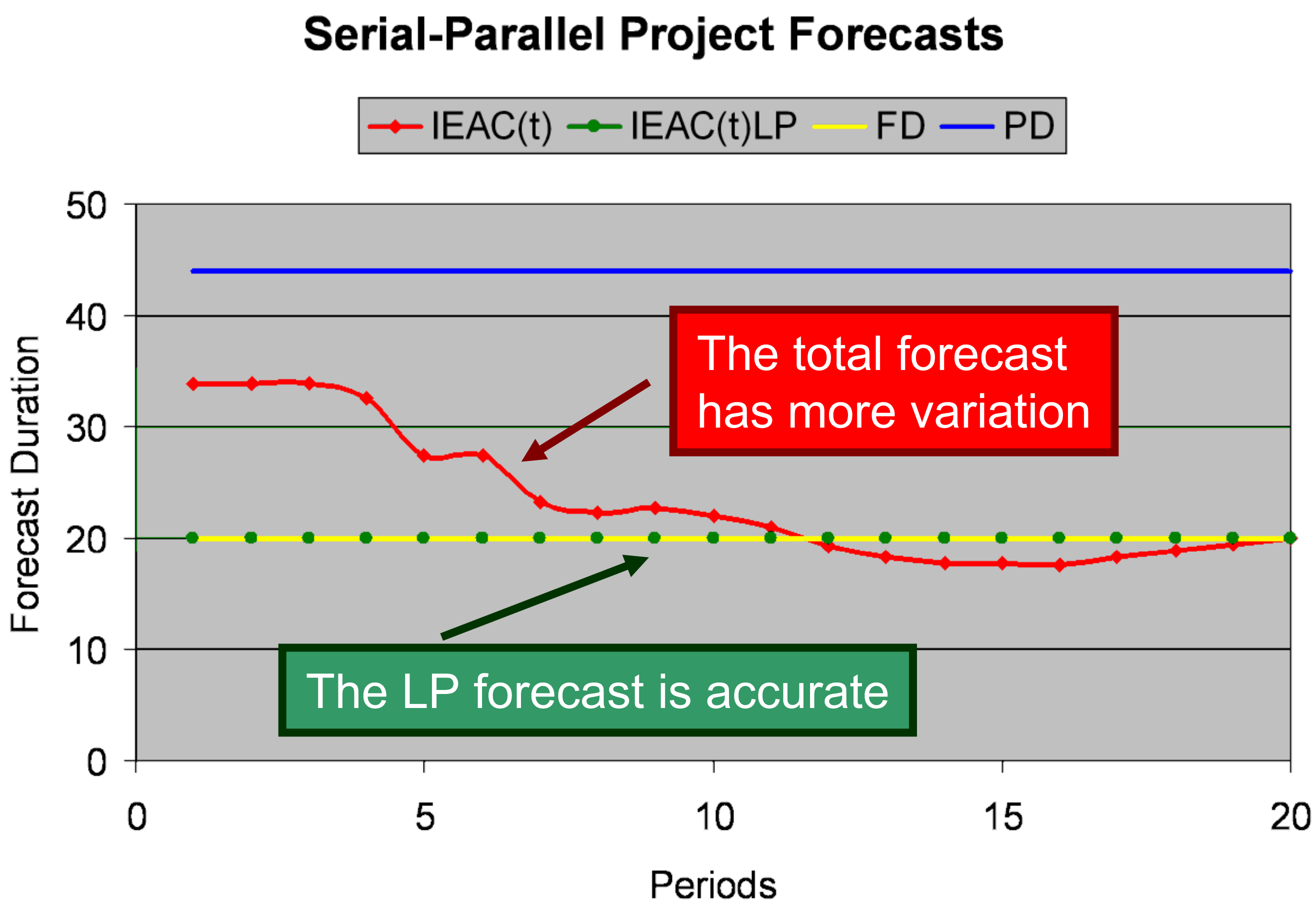
| | Period | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task 1 | PV | | | | | | | | | | | | | | | | | | | | | | |
| | EV | | | | | | | | | | | | | | | | | | | | | | |
| 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

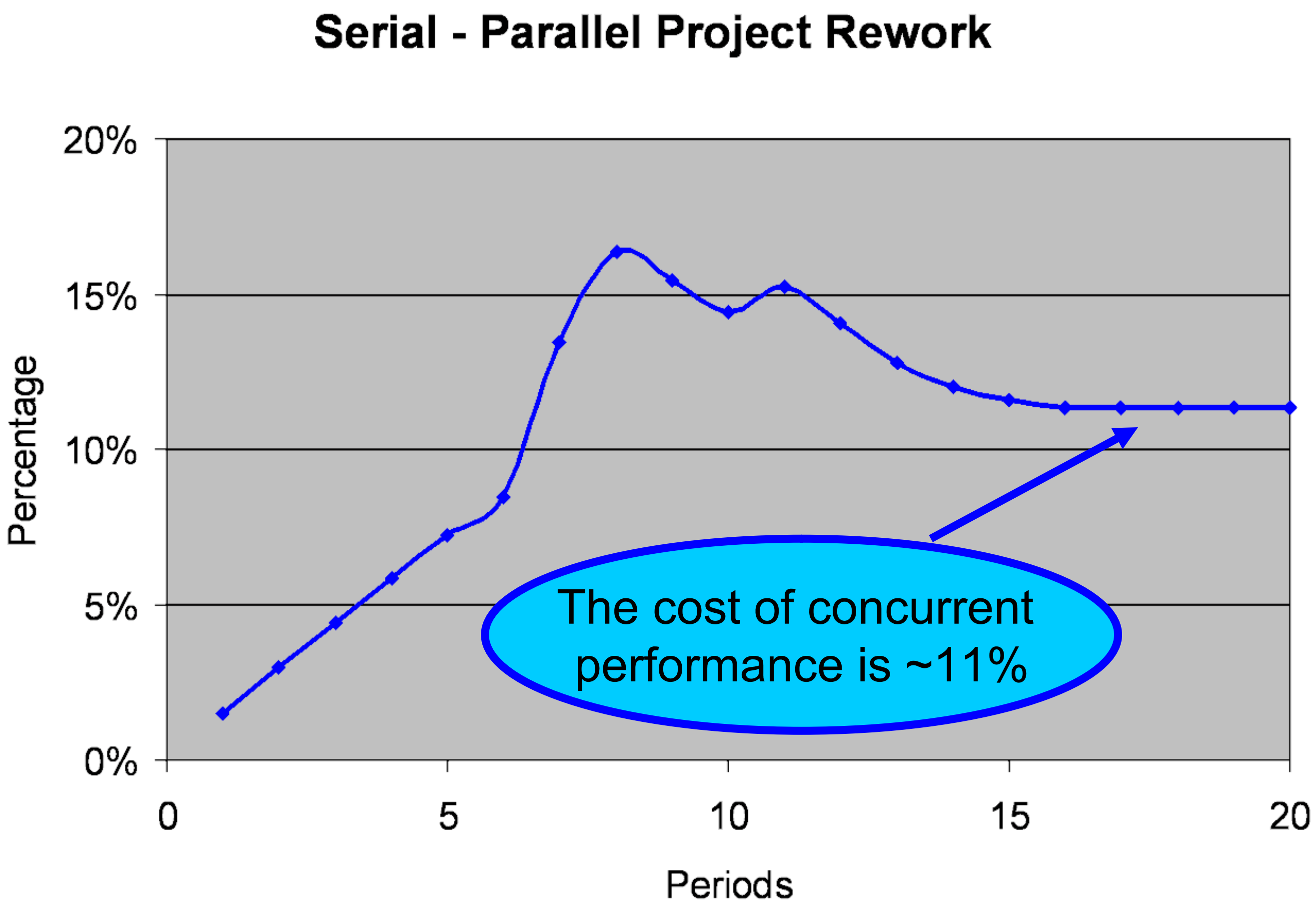


# Example Serial-Parallel



# Example Serial-Parallel



# 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

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# 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

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# 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%

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# 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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