“Forecasting Project Schedule Completion” by Using Earned Value Metrics

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Agenda

- Introduction
- Schedule performance indicators
- Schedule forecasting generic formula
- Method 1: Use of PV Rate (Planned Value Rate)
- Method 2: Use of ED (Earned Duration)
- Method 3: Use of ES (Earned Schedule)
- Discussion of different methods
- Forecasting at project level - Case Study
- Conclusion
Introduction

- Earned Value Management (EVM) as defined in the 2000 Edition of the PMBOK Guide:
  
  *A method for integrating scope, schedule and resources, and for measuring project performance.*

- Definition implies equal weight to both cost & schedule
- Reality is that most EVM metrics focus primarily on cost
- EVM was developed for cost measurement, not scheduling

- There is currently a trend to use performance indicators for predicting project duration.
- 3 methods are presented here.
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Schedule Variance (SV)

SV = Earned Value - Planned Value = EV - PV

Positive (+) variance: volume of work performed ahead of plan
Negative (-) variance: volume of work performed behind plan

- SV does not measure time, it measures volume of work done versus planned on same basis (Euros)
- SV does not identify work, requires “drill down” analysis
- “+” may be bad: work done not on critical path, offsetting tasks
- “-” may be good: work behind has float, offsetting tasks
- SV is zero at end of project, even when project is late

Suggestions for other name:
“Progress Variance” or “Accomplishment Variance”
Example - SV

Early Finish Project

Late Finish Project
Schedule Performance Index (SPI)

SPI = Earned Value / Planned Value = EV / PV

SPI > 1: volume of work performed ahead of plan
SPI = 1: volume of work performed according to plan
SPI < 1: volume of work performed behind plan

- SPI does not have a “dimension”
- SPI does not identify work, requires “drill down” analysis
- “ >1 ” may be bad: work done not on critical path, offsetting tasks
- “ <1 ” may be good: work behind has float, offsetting tasks
- SPI equals 1 at end of project: even when project is late, the index shows a perfect schedule performance
Example - SPI
Discussion of schedule metrics

- Strengths of SV & SPI:
  - Provides a reliable early warning
  - Reflects cost/schedule integration

- Weaknesses of SV & SPI:
  - SV initially follows a trend, but moves towards 0, even if project is late
  - SPI initially follows a trend, but moves towards 1, even if project is late
  - SV & SPI does not indicate the real performance of the project

- At a certain point in time, the SV & SPI are no more reliable for forecasting purposes.
- This “grey area” occurs usually the last third of the project.
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EDAC = Actual Duration + Estimated Duration Work Remaining
EDAC = AD + EDR

- EDAC = Estimated Duration at Completion
- AD = Actual Duration (time now)
- EDR = Estimated Duration of Remaining Work

- The EDR is the portion to “guess at best”
- The Estimated Duration of Work Remaining is influenced by the project environment
- 6 types are defined
Types of EDR Estimates (1)

- **Case 1: new EDR estimate**
  - occurs when original assumptions are no longer valid
  - a new estimate (new schedule) needs to be developed
  - forecasting formulas are useless in this case

- **Case 2: EDAC as planned**
  - project will be on schedule, even when prior performance is poor
  - f.e. “we’ll catch up during the testing phase”
  - can be dangerous, as unfixed problems don’t fix themselves

- **Case 3: EDR substantially higher as planned**
  - f.e. additional time is needed to fix various problems
  - estimate in general not quantified
  - more common as we believe
Types of EDR Estimates (2)

- Case 4: EDR as planned
  - past schedule problems will not occur in the future
  - future progress will be according to plan

- Case 5: EDR will continue with current SPI trend
  - past problems will continue in the future
  - f.e. because of delaying corrective actions, is a realistic case

- Case 6: EDR will continue with current SCI trend
  - SCI = critical ratio = CPI * SPI
  - used when adherence to budget is critical to organization
## Forecasting Methods

### Case

<table>
<thead>
<tr>
<th>Case</th>
<th>Forecast Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDAC = new</td>
<td>re-schedule</td>
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<tr>
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<td>monitor schedule</td>
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<td>EDR will follow current SPI trend</td>
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<tr>
<td>EDR will follow current SCI trend</td>
<td>EDACpv3 EDACed3 EDACes3</td>
</tr>
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</table>

**EDAC = Estimated Duration at Completion**

** Forecasting Project Schedule Completion with EV Metrics, The Measurable News, Summer 2004
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Method 1: PV Rate

PV Rate = BAC / TAC

- PV Rate = Planned Value Rate (€/month, €/week, ...)
- TAC = Time at Completion, number of periods (months, weeks, ...)
- BAC = Budget at Completion

TV = SV / PV Rate

- TV = Time Variance (months, weeks, ...)
- SV = Schedule Variance
Method 1: PV Rate

- EDR according to plan
  \[ EDAC_{pv1} = \frac{TAC - TV}{SPI} \]

- EDR with continued SPI performance
  \[ EDAC_{pv2} = \frac{TAC}{SPI} \]

- EDR with continued SCI performance
  \[ EDAC_{pv3} = \frac{TAC}{SCI} \]
**Method 1:** example

**Scope:** install 350 TFT Monitors, 50 monitors / week  
**TAC:** 7 weeks  
**BAC:** 35,000 € (100 € / monitor)

<table>
<thead>
<tr>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
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<td>0,79</td>
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</table>

**PV Rate** = **BAC / TAC** = 35,000 / 7 = 5,000 € / week  
**TV** = **SV / PV Rate** = (12,000 - 15,000) / 5,000 = -0,6 weeks

**EDACpv1** = **TAC - TV** = 7 - (-0,6) = 7,6 weeks  
**EDACpv2** = **TAC / SPI** = 7 / 0,80 = 8,75 weeks  
**EDACpv3** = **TAC / SCI** = 7 / 0,75 = 9,33 weeks
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Method 2: ED Method

**ED = AD * SPI**

- ED = Earned Duration
- AD = Actual Duration
- SPI = Schedule Performance Index

**EDAC = AD + (TAC - ED) / P.F.**

- EDAC = Estimated Duration at Completion
- TAC = Time at Completion
- ED = Earned Duration
- P.F. = Performance factor (according to different cases)
Method 2: ED Method

- EDR according to plan (P.F. = 1)
  \[ EDACed1 = AD + \frac{(TAC - ED)}{1} = TAC + AD \times (1 - SPI) \]

- EDR with continued SPI performance (P.F. = SPI)
  \[ EDACed2 = AD + \frac{(TAC - ED)}{SPI} = \frac{TAC}{SPI} \]

- EDR with continued SCI performance
  - proposed in reference:
    \[ EDACed3 = \frac{TAC}{SCI} \]

  - mathematically correct:
    \[ EDACed3m = \frac{TAC}{SCI} + AD \times (1-1/CPI) \]
Method 2: Extension

Corrective action metric: TCSPI

TCSPI = (TAC - ED) / (TAC - AD)

TCSPI = To Complete Schedule Performance Index

a measure of the required performance needed to bring in the project on the planned time

TCSPI = (TAC - ED) / (EDAC - AD)

TCSPI = To Complete Schedule Performance Index

a measure of the required performance needed to bring in the project on the estimated EDAC time
Method 2: Extension

What when work is not finished and planned duration is passed?

- Mathematically: $AD > PD$ and $SPI < 1$
- TAC is being replaced by $AD$

$EDACed1 = AD (2 - SPI)$

$EDACed2 = AD / SPI$

$EADCd3 = AD / SCI$

$EADCd3m = AD (1 - 1/CPI + 1/SCI)$
Method 2: example

Scope: install 350 TFT Monitors, 50 monitors / week
TAC: 7 weeks
BAC: 35.000 € (100 € / monitor)

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ED = AD x SPI = 3 x 0.8 = 2.4 weeks

EDACed1 = TAC + AD (1 - SPI) = 7 + 3 (1 - 0.80) = 7.6 weeks
EDACed2 = TAC / SPI = 7 / 0.80 = 8.75 weeks
EDACed3 = TAC / SCI = 7 / 0.75 = 9.33 weeks

EDACed3m = TAC / SCI + AD (1 - 1/CPI) = 9.14 weeks
Method 2: example

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TCSPI = (TAC - ED) / (TAC - AD) = (7 - 2.4) / (7 - 3) = 1.15
TCSPI = (TAC - ED) / (EDACed1 - AD) = 1.00
TCSPI = (TAC - ED) / (EDACed2 - AD) = 0.80
TCSPI = (TAC - ED) / (EDACed3 - AD) = 0.73

TCSPI = (TAC - ED) / (EDACed3m - AD) = 0.75
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Method 3: Earned Schedule

- Idea of “Earned Schedule” is identical as “Earned Value”

- Instead of using cost for measuring schedule performance, we will use “time”

- “Earned Schedule” is determined by comparing Earned Value to the performance baseline (= planned value). The time associated with the Earned Value is found from the PV-curve.

- So we project the Earned Value onto the Planned Value curve
EV vs. ES - Graphical Display

**Earned Value**
- **AC**
- **PV**
- **EV**

**Earned Schedule**
- **ES**
- **AT**

Projection of EV onto PV

**Timeline**
- **CV**
- **SV**
ES Calculation

\[
ES = N + \frac{(EV - PV_N)}{(PV_{N+1} - PV_N)}
\]

- **ES** = Earned Schedule
- **N** = time increment of PV that is less than current PV
- **PV_N** = Planned Value at time N
- **PV_{N+1}** = Planned Value at time N + 1
ES Derived Metrics

Derived metrics, similar to the “classical” Earned Value:

\[ SV(t) = ES - AT \]
- “positive” = ahead of schedule
- “negative” = lagging

\[ SPI(t) = \frac{ES}{AT} \]
- “>1” = ahead of schedule
- “>1” = lagging

\[ EDAC = AT + \text{Estimated Remaining Time to Completion} \]
\[ = AT + \frac{(TAC - ES)}{P.F.} \]
ES Forecasting

- EDR according to plan (P.F. = 1)
  \[ \text{EDACes1} = \text{AD} + \frac{\text{TAC} - \text{ES}}{\text{SPI}(t)} \]

- EDR with continued SPI(t) performance
  \[ \text{EDACes2} = \text{AD} + \frac{\text{TAC} - \text{ES}}{\text{SPI}(t)} \]

- EDR with continued SPI performance
  \[ \text{EDACes3} = \text{AD} + \frac{\text{TAC} - \text{ES}}{\text{SCI}(t)} \]

- Corrective Action Metric
  \[ \text{TCSPI}(t) = \frac{\text{TAC} - \text{ES}}{\text{TAC} - \text{AT}} \]
Method 3: example

Scope: install 350 TFT Monitors, 50 monitors / week
TAC: 7 weeks
BAC: 35.000 € (100 € / monitor)

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<td>N</td>
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<td>SCI(t)</td>
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<td>0,75</td>
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</tr>
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EDACes1 = AD + (TAC - ES) = 3 + (7 - 2,4) = 7,6 weeks
EDACes2 = AD + (TAC - ES) / SPI(t) = 8,75 weeks
EDACes3 = AD + (TAC - ES) / SCI(t) = 9,33 weeks

TCSPI(t) = (TAC - ES) / (TAC - AT) = (7 - 2,4) / (7 - 3) = 1,15
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Discussion of different methods

- Forecasting at project level - Case Study
- Conclusion
Summary of Results

<table>
<thead>
<tr>
<th>Case</th>
<th>Anbari (*)</th>
<th>Jacob (**)</th>
<th>Lipke (***)</th>
<th>Forecast Method</th>
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<tr>
<td>1 EDAC = new</td>
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<td>re-schedule</td>
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<tr>
<td>2 EDAC as originally planned</td>
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<td>monitor schedule</td>
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<td>3 EDAC is very high</td>
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<td>re-schedule</td>
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<td>5 EDR will follow current SPI trend</td>
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<tr>
<td>6 EDR will follow current SCI trend</td>
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<td>9,33 (9,14)</td>
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</table>

⇒ All results are the same!
⇒ Why?
Why are Results the Same?

- All methods apply the same basic parameters (EV, PV, …)
- All methods are based on sound analytical thought
- Formulas used in methods are linear, as well as the used PV in the example.
- If the PV is non-linear, differences between the methods could be introduced. These “errors” can be reduced by using smaller time increments (more reporting periods)
Non Linear PV Rate

Scope: install 350 TFT Monitors, including learning curve
TAC: 7 weeks
BAC: 35,000 € (100 € / monitor)

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## Results - Non Linear PV - W3

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<td></td>
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</tr>
<tr>
<td>3  EDAC is very high</td>
<td>re-schedule</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4  EDR according to plan</td>
<td></td>
<td>6,10</td>
<td>5,20</td>
<td>6,00</td>
</tr>
<tr>
<td>5  EDR will follow current SPI trend</td>
<td></td>
<td>4,38</td>
<td>4,38</td>
<td>5,25</td>
</tr>
<tr>
<td>6  EDR will follow current SCI trend</td>
<td></td>
<td>4,65</td>
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<td>5,39</td>
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</table>

<table>
<thead>
<tr>
<th>Planned Value Rate</th>
<th>Earned Duration</th>
<th>Earned Schedule</th>
</tr>
</thead>
</table>
Discussion

- Results are no longer identical, and depends on used method.

- The Earned Schedule method appears to forecast higher durations, compared with other methods.

- But most important:
  So far we applied the formulas to a single activity.
  How do the methods behave on higher WBS levels?
  Which method is the best?
Agenda

- Introduction
- Schedule performance indicators
- Schedule forecasting generic formula
- Method 1: Use of PV Rate (Planned Value Rate)
- Method 2: Use of ED (Earned Duration)
- Method 3: Use of ES (Earned Schedule)
- Discussion of different methods

- Forecasting at project level
- Case Study

- Conclusion
Case Study

973.xxx C.I. 6 - R11/12
Scope: revamping of C.I. Island
BAC: 360.738 €
TAC: 9 months
WBS: Project Level
## Case Study - EV Metrics

<table>
<thead>
<tr>
<th></th>
<th>juin-02</th>
<th>juil-02</th>
<th>août-02</th>
<th>sept-02</th>
<th>oct-02</th>
<th>nov-02</th>
<th>déc-02</th>
<th>janv-03</th>
<th>févr-03</th>
<th>mars-03</th>
<th>avr-03</th>
<th>mai-03</th>
<th>juin-03</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>25.645</td>
<td>68.074</td>
<td>89.135</td>
<td>125.244</td>
<td>198.754</td>
<td>268.763</td>
<td>292.469</td>
<td>306.725</td>
<td>312.864</td>
<td>327.694</td>
<td>338.672</td>
<td>349.861</td>
<td>360.738</td>
</tr>
<tr>
<td>SPI</td>
<td>0.89</td>
<td>0.83</td>
<td>0.97</td>
<td>0.90</td>
<td>0.91</td>
<td>0.89</td>
<td>0.90</td>
<td>0.89</td>
<td>0.87</td>
<td>0.91</td>
<td>0.94</td>
<td>0.97</td>
<td>1.00</td>
</tr>
</tbody>
</table>

![Graph](image1.png)

![Graph](image2.png)
### Case Study - ES Calculation

#### Example ES Calculation (period 09/02, 4th period):

\[
ES = 3 + \frac{125.244 - 91.681}{138.586 - 91.681} = 3.716 \text{ months}
\]

#### Example ES Calculation (period 01/03, 8th period):

\[
ES = 6 + \frac{306.725 - 302.478}{323.632 - 302.478} = 6.201 \text{ months}
\]

<table>
<thead>
<tr>
<th></th>
<th>juin-02</th>
<th>juil-02</th>
<th>août-02</th>
<th>sept-02</th>
<th>oct-02</th>
<th>nov-02</th>
<th>déc-02</th>
<th>janv-03</th>
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<th>avr-03</th>
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<tbody>
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<td>290,843</td>
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<td>316,431</td>
<td>320,690</td>
<td>336,756</td>
<td>349,379</td>
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<td><strong>EV</strong></td>
<td>25,645</td>
<td>68,074</td>
<td>89,135</td>
<td>125,244</td>
<td>198,754</td>
<td>268,763</td>
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<td>327,694</td>
<td>338,672</td>
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<tr>
<td><strong>PV</strong></td>
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<td>138,586</td>
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<td>360,738</td>
<td>360,738</td>
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</tr>
<tr>
<td><strong>SPI</strong></td>
<td>0,89</td>
<td>0,83</td>
<td>0,97</td>
<td>0,90</td>
<td>0,91</td>
<td>0,89</td>
<td>0,90</td>
<td>0,89</td>
<td>0,87</td>
<td>0,91</td>
<td>0,94</td>
<td>0,97</td>
<td>1,00</td>
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</table>

#### Table

<table>
<thead>
<tr>
<th></th>
<th>AT</th>
<th>ES</th>
<th>PT</th>
<th>SV(t)</th>
<th>SPI(t)</th>
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<td><strong>ES</strong></td>
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<td>0,84</td>
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<tr>
<td></td>
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<td>6,201</td>
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<td>0,72</td>
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<tr>
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<td>7,183</td>
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<td>7,676</td>
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<td>0,70</td>
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<td>8,268</td>
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<td>-3,732</td>
<td>0,69</td>
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<tr>
<td></td>
<td>13</td>
<td>9,000</td>
<td>9</td>
<td>-4,000</td>
<td>0,69</td>
</tr>
</tbody>
</table>
Case Study - ES Calculation

Example SPI(t) Calculation (period 12/02, 7th period):

- SPI(t) = 5,881 / 7 = 0,84
- Project is progressing at a rate of 0,78 months for each month of actual time

Example SV(t) Calculation (period 12/02, 7th period):

- SV(t) = 5,881 - 7 = - 1,119
- Project lags its expected performance by 1,119 months
Case Study - SV vs. SV(t)
Case Study - SPI vs. SPI(t)

In this timeframe, SPI & SPI(t) correlates very well. At 11/02, or at the ca. 75% completion point, the SPI becomes unreliable.
Case Study - EDAC P.F. = 1

At 11/02, or at the ca. 75% completion point, the IDACes is clearly more accurate.

PV Rate Method: correlates well at early stages, but is useless towards the end
ED Method: correlates well till 75% completion point
ES Method: predicts more accurate towards the final stages
Case Study - EDAC P.F. = SPI

At 11/02, or at the ca. 75% completion point, the IDACes is clearly more accurate.

PV Rate Method: correlates well at early stages, but is useless towards the end
ED Method: correlates well till 75% completion point
ES Method: predicts more accurate towards the final stages
Case Study - EDAC P.F. = SCI

At 11/02, or at the ca. 75% completion point, the EDACes is clearly more accurate.

**PV Rate Method:** correlates well at early stages, but is useless towards the end.

**ED Method:** correlates well till 75% completion point.

**ES Method:** predicts more accurate towards the final stages.
Case Study - ED vs. ES
Discussion

- **During early and middle project stage**
  - All methods seem to correlate well
  - All methods produce same results within the same range

- **During late project stage**
  - The PV Rate method is useless and meaningless
    (at project level, the PV is non-linear, but follows a S-curve)
  - The ED method tends to underestimate the final duration
    (remember the strange SPI behaviour, the “grey area”)
  - The ES method produces the best forecast results
At M6-7, or at the ca. 70% completion point, the IDACes is clearly more accurate.
Agenda

- Introduction
- Schedule performance indicators
- Schedule forecasting generic formula
- Method 1: Use of PV Rate (Planned Value Rate)
- Method 2: Use of ED (Earned Duration)
- Method 3: Use of ES (Earned Schedule)
- Discussion of different methods
- Forecasting at project level - Case Study

Conclusion
The use of EV metrics to forecast the schedule should happen at least on the overall project level (early warning signal):

- for early and middle project stages, each method can be used
- for late project stage (mostly the most important period), the ES method produces clearly the best results

- When performance is poor, a “drill-down” into the lower WBS levels will help detect the troubled tasks

- If tasks are on the critical path, evaluation of the forecasted duration impact can be made

- The use of “earned duration” and “earned schedule” metrics is NOT a replacement for scheduling tools such as PERT, CPM, Monte Carlo scheduling
### Forecasting Methods

#### At early and middle stage

<table>
<thead>
<tr>
<th>Forecast Method</th>
<th>PV Rate</th>
<th>ED</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDR according to plan</td>
<td>TAC - TV</td>
<td>TAC + AD (1 - SPI)</td>
<td>AD + (TAC - ES)</td>
</tr>
<tr>
<td>EDR will follow current SPI trend</td>
<td>TAC / SPI</td>
<td>TAC / SPI</td>
<td>AD + (TAC - ES) / SPI(t)</td>
</tr>
<tr>
<td>EDR will follow current SCI trend</td>
<td>TAC / SCI</td>
<td>TAC / SCI</td>
<td>AD + (TAC - ES) / SPI(t)</td>
</tr>
</tbody>
</table>

#### At late stage

<table>
<thead>
<tr>
<th>Forecast Method</th>
<th>PV Rate</th>
<th>ED</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDR according to plan</td>
<td>---</td>
<td>---</td>
<td>AD + (TAC - ES)</td>
</tr>
<tr>
<td>EDR will follow current SPI trend</td>
<td>---</td>
<td>---</td>
<td>AD + (TAC - ES) / SPI(t)</td>
</tr>
<tr>
<td>EDR will follow current SCI trend</td>
<td>---</td>
<td>---</td>
<td>AD + (TAC - ES) / SPI(t)</td>
</tr>
</tbody>
</table>
Conclusion

- SPI & SV indicators are flawed and exhibit strange behaviour over the final third of the project, and are as a consequence not reliable.

- The use of the “Earned Schedule” method provides indicators SPI(t) & SV(t), which behave correctly during the project life.

- It has been demonstrated that the use of ES metrics provides a more reliable forecast for total project duration.

- Why not starting to use the “earned schedule method” as a standard procedure?