Earned Schedule

schedule performance analysis from EVM measures

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

\[ \text{PV} = \text{SV} \]

Time Periods

Eva Europe
Geneva 2009

CERN

Heeg

Heute einheit der gestalt der Zukunft
Geneva School of Business Administration

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Importance of Schedule

“We need to maintain our attention on schedule delivery. Data tells us that since July 2003, real cost increase in projects accounted for less than 3 percent of the total cost growth.

…Therefore, our problem is not cost, it is SCHEDULE.”

- Dr. Steve Gumley, CEO
  Defence Materiel Organization (Australia)

Quote taken from DMO Bulletin, July 2006, Issue 61, page
Overview

- Earned Schedule Concept
- Calculation of Earned Schedule
- Time-Based Schedule Indicators
- Project Duration Prediction & Forecasting
- Critical Path Analysis
- Network Schedule Analysis
- Demonstration of the ES Spreadsheet
Earned Value Basics

\[ \text{CPI} = \frac{\text{EV}}{\text{AC}} \]

\[ \text{SPI} = \frac{\text{EV}}{\text{PV}} \]

\[ \text{SV} = \text{EV} - \text{PV} \]

\[ \text{PV} = \text{Planned Value} \]

\[ \text{EV} = \text{Earned Value} \]

\[ \text{AC} = \text{Actual Cost} \]

\[ \text{BAC} = \text{Budget at Completion} \]

\[ \text{PD} = \text{Planned Duration} \]

Something’s wrong!!

PV = Planned Value
EV = Earned Value
AC = Actual Cost
BAC = Budget at Completion
PD = Planned Duration
EVM Schedule Indicators

- SV & SPI behave erratically for projects behind schedule
  - SPI improves and equals 1.00 at end of project
  - SV improves and concludes at $0 variance
- Schedule indicators lose predictive ability over the last third of the project
- Why does this happen?
  - SV = EV – PV
  - SPI = EV / PV

At planned completion PV = BAC
At actual completion EV = BAC
The idea is to determine the time at which the EV accrued should have occurred.

For the above example, ES = 5 months …that is the time associated with the PMB at which PV equals the EV accrued at month 7.
Earned Schedule Metric

- Required measures
  - **Performance Measurement Baseline** (PMB) – the time phased planned values (PV) from project start to completion
  - **Earned Value** (EV) – the planned value which has been “earned”
  - **Actual Time** (AT) - the actual time duration from the project beginning to the time at which project status is assessed

- **All measures available from EVM**
Earned Schedule Calculation

- **ES (cumulative)** is the:
  Number of complete PV time increments EV equals or exceeds + the fraction of the incomplete PV increment

- **ES = C + I** where:
  
  \[ C = \text{number of time increments for } EV \geq PV \]
  
  \[ I = \frac{(EV - PV_C)}{(PV_{C+1} - PV_C)} \]
Interpolation Calculation

\[
\frac{I}{1 \text{ mo}} = \frac{p}{q}
\]

\[
I = \left(\frac{p}{q}\right) \times 1 \text{ mo}
\]

\[
p = EV - PV_C
\]

\[
q = PV_{C+1} - PV_C
\]

\[
I = \frac{EV - PV_C}{PV_{C+1} - PV_C} \times 1\text{mo}
\]

Subscript C identifies the planned value period at which EVcum ≥ PV_{cum}
Earned Schedule Indicators

- Schedule Variance:
  \[ SV(t) = ES - AT \]

- Schedule Performance Index:
  \[ SPI(t) = \frac{ES}{AT} \]
  where AT is “Actual Time” – the duration from start to time now

- \( SV(t) \) and \( SPI(t) \) are time-based (months, weeks …)
ES Computation Example

**SPI($) =** \( \frac{EV}{PV} \)

**SPI(t) =** \( \frac{ES}{AT} \)

**SV($) =** \( EV - PV \)

**SV(t) =** \( ES - AT \)

**ES** = All of May + Portion of June

\[ ES = 5 + \frac{EV - PV(May)}{PV(June) - PV(May)} \]

\[ AT = 7 \]
ES Computation Example

Earned Schedule requires the:
1) PMB; and
2) Accrued EV for calculation.
The equation is: \( ES = C + I \)

The first step is to compute C. The value of C is found by counting the number of the PV time increments EV equals or exceeds.
In this example the count is from January through May. \( C = 5 \) (months).

ES = All of May + Portion of June
\[ ES = 5 + \frac{EV - PV(May)}{PV(June) - PV(May)} \]
\[ AT = 7 \]
Thus far, ES = 5 + I (months).

In the small box at the lower right, is the equation for calculating I.

For the example, let
1) EV = 100
2) PV₅ (May) = 90
3) PV₆ (June) = 110.

Let’s calculate I:
I = (100 - 90) / (110 - 90) = 0.5

ES = 5 + 0.5 = 5.5 (months)

From ES (5.5 months) we can now calculate the ES indicators: SV(t) and SPI(t).

The EV is reported at Actual Time. AT = 7, the end of June.

SV(t) = 5.5 - 7 = - 1.5 months

SPI(t) = 5.5 / 7 = 0.79
Earned Schedule Indicators

- What happens to the ES indicators, SV(t) & SPI(t), when the planned project duration (PD) is exceeded (PV = BAC)?
  
  They Still Work ...Correctly!!

- ES will be \( \leq \) PD, while AT > PD
  
  - SV(t) will be negative (time behind schedule)
  - SPI(t) will be < 1.00

  Reliable Values from Start to Finish!!
SV Comparison

Early Finish Project

Late Finish Project

SV($)  SV(t)
SPI Comparison

Early Finish Project

Late Finish Project
Late Finish Project

Commercial IT Infrastructure Expansion Project Phase 1
Cost and Schedule Variances
at Project Projection: Week Starting 15th July xx

- CV cum
- SV cum
- Target SV & CV
- SV (t) cum

Stop wk 19
Sched wk 20
Re-start wk 26
Schedule Prediction

- Can the project be completed as planned?
  - TSPI = Plan Remaining / Time Remaining
    - \( TSPI = \frac{PD - ES}{PD - AT} \)
  - where \( PD \) is the planned duration (time at BAC)
  - \( PD - ES = PDWR \)
  - \( PDWR = \) Planned Duration for Work Remaining

- …completed as estimated?
  - TSPI = (PD – ES) / (ED – AT)
  - where \( ED = \) Estimated Duration

<table>
<thead>
<tr>
<th>TSPI Value</th>
<th>Predicted Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 1.00 )</td>
<td>Achievable</td>
</tr>
<tr>
<td>( &gt; 1.10 )</td>
<td>Not Achievable</td>
</tr>
</tbody>
</table>
Schedule Forecasting

- Long time goal of EVM … *Prediction of total project duration from present schedule status*

- Independent Estimate at Completion (time)
  - $\text{IEAC}(t) = \frac{\text{PD}}{\text{SPI}(t)}$
  - $\text{IEAC}(t) = \text{AT} + \frac{\text{PD} - \text{ES}}{\text{PF}(t)}$
    where $\text{PF}(t)$ is the Performance Factor (time)
  - Analogous to IEAC used to forecast final cost

- Independent Estimated Completion Date (IECD)
  - $\text{IECD} = \text{Start Date} + \text{IEAC}(t)$
Performance Confirmation

- SPI(t) & SV(t) do portray the real schedule performance
- At early & middle project stages pre-ES & ES forecasts of project duration produce similar results
- At late project stage ES forecasts outperform all pre-ES forecasts
- “The use of the SPI(t) in conjunction with the TSPI has been demonstrated to be useful for managing the schedule.”  
  Stephan Vandevoorde – Fabricom Airport Systems, Belgium
- “The results reveal that the earned schedule method outperforms, on the average, all other forecasting methods.”  
  Dr. Mario Vanhoucke & Stephan Vandevoorde
Research Results

Forecast Accuracy and the Completion of Work

Simulation runs performed: 1 run project finish ahead of schedule, 1 run projects finish behind

Mean Percentage Error (MPE) for early finish projects

Mean Percentage Error (MPE) for late finish projects

## Research Results

### Hypothesis Test Results - EVM vs ES Time Forecast

<table>
<thead>
<tr>
<th>Significance</th>
<th>10% - 40%</th>
<th>40% - 70%</th>
<th>70% - 100%</th>
<th>10% - 100%</th>
<th>25% - 100%</th>
<th>50% - 100%</th>
<th>75% - 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>α = 0.05</strong></td>
<td>0.0000</td>
<td>0.0267</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0000</td>
</tr>
<tr>
<td><strong>Test Statistic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sign Test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ha</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Count #1s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ES</strong></td>
<td>11</td>
<td>7</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td><strong>EVM</strong></td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

**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
# Earned Schedule Terminology

<table>
<thead>
<tr>
<th>Status</th>
<th>EVM</th>
<th>Earned Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
<td>SV(t)</td>
<td>SV(t)</td>
</tr>
<tr>
<td>SPI</td>
<td>SPI(t)</td>
<td>SPI(t)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Future Work</th>
<th>EVM</th>
<th>Earned Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budgeted Cost for Work Remaining (BCWR)</td>
<td>Planned Duration for Work Remaining (PDWR)</td>
<td></td>
</tr>
<tr>
<td>Estimate to Complete (ETC)</td>
<td>Estimate to Complete (time) ETC(t)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prediction</th>
<th>EVM</th>
<th>Earned Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance at Completion (VAC)</td>
<td>Variance at Completion (time) VAC(t)</td>
<td></td>
</tr>
<tr>
<td>Estimate at Completion (EAC) (supplier)</td>
<td>Estimate at Completion (time) EAC(t) (supplier)</td>
<td></td>
</tr>
<tr>
<td>Independent EAC (IEAC) (customer)</td>
<td>Independent EAC (time) IEAC(t) (customer)</td>
<td></td>
</tr>
<tr>
<td>To Complete Performance Index (TCPI)</td>
<td>To Complete Schedule Performance Index (TSPI)</td>
<td></td>
</tr>
</tbody>
</table>
# Earned Schedule Terminology

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Earned Schedule</th>
<th>ES_{cum}</th>
<th>ES = C + I number of complete periods (C) plus an incomplete portion (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Time</td>
<td>AT_{cum}</td>
<td>AT = number of periods executed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicators</th>
<th>SV(t)</th>
<th>SV(t) = ES – AT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule Variance</td>
<td>SV(t)%</td>
<td>SV(t)% = (ES – AT) / ES</td>
</tr>
<tr>
<td>Schedule Performance Index</td>
<td>SPI(t)</td>
<td>SPI(t) = ES / AT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To Complete Schedule Performance Index</th>
<th>TSPI(t)</th>
<th>TSPI(t) = (PD – ES) / (PD – AT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSPI(t)</td>
<td>TSPI(t) = (PD – ES) / (ED – AT)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Predictors</th>
<th>IEAC(t)</th>
<th>IEAC(t) = PD / SPI(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Estimate at Completion (time)</td>
<td>IEAC(t)</td>
<td>IEAC(t) = AT + (PD – ES) / PF</td>
</tr>
</tbody>
</table>

EVA Europe 2009
Earned Schedule

Key Points

- ES Indicators constructed to behave in an analogous manner to the EVM Cost Indicators, CV and CPI
- SV(t) and SPI(t)
  - Not constrained by PV calculation reference
  - Provide duration based measures of schedule performance
  - Valid for entire project, including early and late finish
- Facilitates integrated Cost/Schedule Management (*using EVM with ES*)
Schedule Analysis with EVM?

- Most practitioners analyze schedule from the bottom up using the network schedule, independent from EVM
  
  ....“It is the only way possible.”

- Analysis of the Schedule is overwhelming
- Critical Path is used to shorten analysis
  (CP is longest path of the schedule)

- Duration forecasting using Earned Schedule provides a macro-method similar to the method for estimating Cost
  
  A significant advance in practice

- But, there’s more that ES facilitates ....
Facilitates Drill-Down Analysis

- ES can be applied to any level of the WBS, to include task groupings such as the Critical Path
  - Requires creating PMB for the area of interest
  - EV for the area of interest is used to determine its ES

- Enables comparison of forecasts, total project (TP) to Critical Path (CP)
  - Desired result: forecasts are equal
  - When TP forecast > CP forecast, CP has changed
  - When CP > TP, possibility of future problems
ES Bridges EVM to the Schedule
ES Bridges EVM to the Schedule
How Can This Be Used?

- **Tasks behind** – possibility of impediments or constraints can be identified
- **Tasks ahead** – a likelihood of future rework can be identified
- The identification is independent from schedule efficiency
- The identification can be automated

PMs can now have a schedule analysis tool connected to the EVM Data!!
### Schedule Analysis Example

<table>
<thead>
<tr>
<th>Task</th>
<th>PV</th>
<th>PV@ES</th>
<th>EV@AT</th>
<th>EV - PV</th>
<th>I/C or R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0</td>
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</tr>
<tr>
<td>2</td>
<td>12</td>
<td>9</td>
<td>5</td>
<td>-4</td>
<td>I/C</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0</td>
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</tr>
<tr>
<td>4</td>
<td>5</td>
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<td>3</td>
<td>-2</td>
<td>I/C</td>
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<td>R</td>
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<tr>
<td>Total</td>
<td>62</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Leads to …

- Concept of *Schedule Adherence*
  - Most efficient project execution follows the plan
  - ES provides a way to measure how closely execution is to the plan

- *Schedule Adherence* provides a means to refine predictions and forecasts
  - Research underway
  - Application has begun
Enhanced Forecasting Example

Example Data

Reverse Data

Good Prediction Area
Summary

- Derived from EVM data … only
- Provides time-based schedule indicators
- Indicators do not fail for late finish projects
- Application is scalable up/down, just as is EVM
- Schedule prediction is better than any other EVM method presently used
- Facilitates bridging EVM analysis to include the Schedule
- Provides capability to understand source of rework and refine forecasts & predictions
Available Resources

  - Repository for ES Papers and Presentations
- Earned Schedule Website
  http://www.earnedschedule.com/
  - Established February 2006
  - Contains News, Papers, Presentations, ES Terminology, ES Calculators
  - Identifies Contacts to assist with application
- Wikipedia references Earned Schedule
  http://en.wikipedia.org/wiki/Earned_Schedule
ES Spreadsheet

Earned Schedule Calculator (v1)