Applying Earned Value to a Manufacturing Environment

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UTS Masters by Research Student
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Content

- L&A Project Environment
- Earned Value Management (EVM) - Research
- Earned Value (EV) & Earned Schedule (ES) - Theory
- Applying EV & ES - Sample Project
- Application Lessons
L&A - Project Environment

- **Company**
  - SME (~50 employees)
  - Pressure Equipment
  - Petrochemical
- **Project Scope**
  - 3 to 18 months
  - $20k to $7m
  - Design & Build
  - Testing & Painting
  - Transport
EVM - Research Project

**Plan**
- Learn EV Theory
- Extract Project data
- Track projects
- Apply data to the EV method
- Achieve project forecasting

**Outcome**
- Tenders
- Accounts
- Buying
- Project Mgt System
- Strategic Planning

EVM - Isolated System
Centralised System
EVM - Research Project

Benefits

- Project Mgt System
  - Project reporting
  - Cost transparency
  - Tool for project decision making
- Other Business Areas
  - Project Portfolio mgt
  - Estimating feed back
  - Risk management

Challenges

- Implementation
  - Data capture
  - Need for procedures & flexibility in system
- Research Focus
  - Curve Interpretation
  - Forecast validation
  - Integration of system with operations
**EV Theory - Background**

- **History**
  - Introduced in the 1960 through the US Department of Defence
  - Large projects only - costly & complicated to implement
  - These issues limited early uptake in the private sector, however users agreed on the systems principles
  - 2003
    - Research identifying human factors as the uptake barrier rather than the system itself
    - A viable solution to the EVM schedule performance problem was publicly introduced by Walt Lipke, coined as Earned Schedule© (ES)
    - AS4817 – Project Performance Measurement using EV - Introduced
  - 2004
    - ES Principles cited in the release of PMI Practice Standard for EVM
  - 2006
    - AS4817 revised, however ES principles remain outside its scope
EV Theory - Overview

- **Positives**
  - Converts all activities to $ - simplifies cost reporting
  - Links time & costs in a single cumulative report
  - Project performance indicators, use same data set

- **Negatives**
  - EVM schedule indicators use the planned value (PV)
  - PV remain static when project runs late, causing the indicators to lose their management value
  - Schedule variance measured in $, not weeks / months
  - Schedule performance indicator methods do not match the benefits of the cost indicators
**EV Theory - Objective**

Graphically Reports Cumulative Progress

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<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost $k</th>
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<tbody>
<tr>
<td>Material - Heads</td>
<td>$200</td>
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<td>Material - Shell</td>
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<td>Material - Nozzles</td>
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<td>Direct Labour</td>
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<tr>
<td>Engineering</td>
<td>$200</td>
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</table>

**Budget at Completion (BAC)** $1,500

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**Curves**

- **Planned Value (PV)** – Authorised Budget over planned time ‘t’
- **Earned value (EV)** – Value of the budgeted progress at ‘t’
- **Actual Cost (AC)** – Cost of the actual progress at ‘t’
**Budget Terms**

- **Budget at Completion (BAC)**
  - Authorised budget to complete scope of work
  - Sum of allocated budgets plus undistributed budget

- **Undistributed Budget**
  - Budget associated with scope but not yet included in TPB

- **Time Phased Budget (TPB)**
  - Schedule of expenditure for the BAC
  - Performance Measurement Baseline (PMB)

- **Project Budget**
  - Total budget for the project
    - BAC
    - Management reserves
    - Overheads & profit

- **Authorised Project $**
- **Contingencies $**
- **Organisations $**
EV Theory - Measures

Three Measures

- **Planned Value (PV)**
  - Sum of the PV’s for each project task, equates to the Budget at Completion (BAC)
  - Planned time, uses periodic intervals – Weeks / Months
  - PV Curve - Cumulative planned value at the planned time

- **Earned Value (EV)**
  - EV Curve - Cumulative planned value at the actual time

- **Actual Cost (AC)**
  - AC curve - Cumulatively actual cost at the actual time
**EV Theory - Indicators**

**(EV) Cost Indicators**
- Cost Variance (CV) \( CV = EV - AC \)
- Cost Performance Index (CPI) \( CPI = \frac{EV}{AC} \)

**(EV) Schedule Indicators**
- Schedule Variance (SV) \( SV = EV - PV \)
- Schedule Performance Index (SPI) \( SPI = \frac{EV}{PV} \)
**ES Theory - Indicators**

**ES** Schedule Indicators

- Schedule Variance \( SV(t) \) \( SV(t) = ES - AT \)
- Schedule Performance Index \( SPI(t) \) \( SPI(t) = ES / AT \)

**New Terms (using ES method)**

- AT – Actual Time, number of time increments corresponding to EV
- C – Number of whole time increments of PMB for condition \( EV \geq PV \)
- ES – Earned Schedule \( ES = C + I \)
- I – Portion of PMB increment earned \( I = \frac{(EV - PV_C)}{(PV_{C+1} - PV_C)} \)
**EV Theory - When AT < Plan**

- **PV**: Projected Value
- **EV**: Earned Value
- **AC**: Actual Cost
- **CV**: Cost Variance
- **SV**: Schedule Variance

- **Actual Time (AT = 3)**
- **PMB**: Project Management Baseline
- **BAC**: Budget at Completion

**Measurements**:
- **SV(t) ~ 0.8 months late**
- **SV ~ $500k late**
- **ES = 2 full intervals + portion of the 3rd**

**Graph**: Showcases the comparison between actual time and planned time, highlighting cost and schedule variances.
EV Theory - When AT > Plan

CV, remains valid

PV not available for EVM, SV calculation
ES calculation for SV(t) remains valid

Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

PV not available for EVM, SV calculation
ES calculation for SV(t) remains valid

Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
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SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
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SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
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SV = $200k late?

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Actual Time
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SV(t) ~ 3 and bit months late

Actual Time
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Actual Time
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Actual Time
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SV(t) ~ 3 and bit months late

Actual Time
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Actual Time
AT = 7

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Actual Time
AT = 7

SV = $200k late?

SV(t) ~ 3 and bit months late

Actual Time
AT = 7

SV = $200k late?
ES Theory – ES Calculation

\[ ES = C + I \]

\[ I = \frac{I_N}{I_D} = \frac{(EV - PV_C)}{(PV_{C+1} - PV_C)} \]

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

\[ I_N = EV - PV_C \]

A change in EV affects the \( I \) to PV intersection

Change in the \( I \) to PV intersection will move \( I \) on \((t)\), changing ES

3 full intervals + portion of the 4\(^{th}\)
ES Theory - Reporting $SV(t)$
Applying EV - Steps

1. Prepare the BAC
2. Schedule Baseline
3. Time Phased Budget
4. Track the Project using Data & Curves
Applying EV - Sample Project

Nozzles

Heads / Ends

Legs

Shell
## Applying EV - Budget

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost  $</th>
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<tbody>
<tr>
<td>Engineering – Calculations, Drafting, Acceptance</td>
<td>$3,000</td>
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<tr>
<td>Material Delivery – Heads</td>
<td>$30,000</td>
</tr>
<tr>
<td>Material Delivery – Shell</td>
<td>$20,000</td>
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<tr>
<td>Material Delivery – Nozzles</td>
<td>$12,000</td>
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<tr>
<td>Material Delivery – Legs</td>
<td>$8,000</td>
</tr>
<tr>
<td>Build &amp; Test – Shell, end, nozzles, closing end, legs</td>
<td>$23,000</td>
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<tr>
<td>Build &amp; Test – Testing</td>
<td>$2,500</td>
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<tr>
<td>Paint &amp; Dispatch – Deliver to Painter &amp; Site</td>
<td>$3,000</td>
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<tr>
<td>Paint &amp; Dispatch – Painting</td>
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<tr>
<td>Budget at Completion (BAC)</td>
<td>$107,500</td>
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<td>Contingencies &amp; Organisational Allowances</td>
<td>$20,700</td>
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<tr>
<td>Project Budget</td>
<td>$128,200</td>
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</table>

**Authorised Project Budget ➔ The BAC**

- Reserves & Business Costs
- Total budget
## Dates for TPB

- **Engineering Calculations** – Week 1
- **Drafting** – Week 2
- **Acceptance** – Week 6
- **Material Delivery**
  - Heads – Week 4
  - Shell – Week 3
  - Nozzles - Week 3
  - Legs – Week 5
- **Build & Test (Finish dates)**
  - Shell – Week 4
  - End – Week 4
  - Nozzles – Week 6
  - Closing end – Week 6
  - Legs – Week 7
  - Testing – Week 8
- **Paint & Dispatch**
  - To painter – Week 8
  - Paint – Week 10
  - To site – Week 10

### Applying EV - Schedule

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
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<tr>
<td>Applying EV - Sample Project</td>
<td>9.4 wks</td>
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<td>1 Engineering</td>
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<tr>
<td>1.2 Detailing</td>
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<tr>
<td>1.2.1 Drafting</td>
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<td>1.2.2 Submission</td>
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<td>2.1.3 Nozzles</td>
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<td>4 Paint &amp; Dispatch</td>
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<td>4.1 Deliver to painter</td>
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<td>4.2 Paint</td>
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<td>4.3 Deliver to site</td>
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## Applying EV - Time Phase Budget

### Time Phase Budget - Sample Project

#### Project Weeks

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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$107,500</td>
<td></td>
</tr>
<tr>
<td>Reporting date for the period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$102,675</td>
<td></td>
</tr>
</tbody>
</table>

*PV values are added to EV when they occur*

*Actual cost and when they occur are added*

*PV’s from the BAC are assigned a time interval according to the schedule, e.g.;*
- Engineering – Acceptance week 6
- Material Delivery – Heads week 4
### Cumulative Performance

<table>
<thead>
<tr>
<th>Tracking Tools</th>
<th>Project Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Planned Value (PV)</td>
<td>$0</td>
</tr>
<tr>
<td>Earned Value (EV)</td>
<td>$0</td>
</tr>
<tr>
<td>Actual Value (AC)</td>
<td>$0</td>
</tr>
</tbody>
</table>

### Earned Value & Earned Schedule Performance Measurements

<table>
<thead>
<tr>
<th>Measurement Tools</th>
<th>Project Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Cost Variance (CV = EV - AC)</td>
<td>$0</td>
</tr>
<tr>
<td>Schedule Variance (SV = EV - PV)</td>
<td>$0</td>
</tr>
<tr>
<td>Earned Schedule Actual Time (AT)</td>
<td>0</td>
</tr>
<tr>
<td>Whole Time Increment of PMB (C = AT for EV ≥ PV)</td>
<td>0</td>
</tr>
<tr>
<td>Numerator portion of PMB increment earned (IN = (EVAT - PV)C)</td>
<td>$0</td>
</tr>
<tr>
<td>Denominator portion of PMB increment earned (ID = (PV C+1 - PV)C)</td>
<td>$1,500</td>
</tr>
<tr>
<td>Earned Schedule (ES = C + IN/ID)</td>
<td>0.00</td>
</tr>
<tr>
<td>Schedule Variance (time) (SV(t) = ES - AT)</td>
<td>0.00</td>
</tr>
<tr>
<td>Schedule Performance Index (time), (SPI(t) = ES/AT)</td>
<td>1.00</td>
</tr>
</tbody>
</table>
SV(t) Curve sensitivity for short duration / time scales needs consideration when reporting to client.
Applying EV - Lessons

- Baseline scheduling & TPB need accuracy
- Errors in these drivers will be displayed as delays or early finish dates by the indicators
- Balance between effort & the benefits
- For small projects (where scope is tangible) a gut feeling needs to be applied until the systems response is understood
- When is the curve showing a trend – Statistical analysis / filtering curve response over time?
References


Earned Schedule – Background

- Official Earned Schedule (ES) web site is found at; www.earnedschedule.com
- ES concept was conceived during the summer of 2002
- Publicly introduced it in March 2003 with ‘The Measurable News’ article, ‘Schedule is Different’
- Interest has grown in the method which has seen it expand into areas of:
  - Application of statistical methods to improve forecasting
  - Schedule adherence measures relating to EVM’s connection to the network schedule
Walt Lipke
- Developed the Earned Schedule© method
- Professional engineer with a Master’ degree in Physics & Graduate of the US Department of Defense course for Program Managers
- Recently retired deputy chief of the Software Division at the Oklahoma City Air Logistics Centre
- Recently published a book tilted ‘Earned Schedule’

Kim Henderson
- Actively involved with Walt Lipke in the testing and promotion of ES
- He is Sydney based IT professional
- Provided some initial information for the research project noted in slides 4 & 5
- Master of Science in computing from UTS
Supp 3 - Data for Theory Curves

Working for Earned Value & Earned Schedule Sample - Slides 13 to 16

<table>
<thead>
<tr>
<th>Curves</th>
<th>EV Curve Data ($k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Value (PV)</td>
<td>$0</td>
</tr>
<tr>
<td>Earned Value (EV)</td>
<td>$0</td>
</tr>
<tr>
<td>Actual Cost (AC)</td>
<td>$0</td>
</tr>
<tr>
<td>Time Increments</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ES Inputs</th>
<th>Calculation for ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Time (AT)</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td><strong>C</strong> = Whole time increment of PMB for condition EV&gt;=PV</td>
<td></td>
</tr>
<tr>
<td>0 0 1 2 2 3 3 3 6</td>
<td></td>
</tr>
<tr>
<td><strong>Numerator portion of PMB</strong></td>
<td></td>
</tr>
<tr>
<td>0 50 100 100 400 100 150 200 0</td>
<td></td>
</tr>
<tr>
<td><strong>Denominator portion of PMB</strong></td>
<td></td>
</tr>
<tr>
<td>150 150 350 600 600 250 250 -1,500</td>
<td></td>
</tr>
<tr>
<td><strong>ES</strong> = C + IN/ID</td>
<td></td>
</tr>
<tr>
<td>0.00 0.33 1.29 2.17 2.67 3.40 3.60 3.80 6.00</td>
<td></td>
</tr>
<tr>
<td><strong>SV</strong> = ES – AT</td>
<td></td>
</tr>
<tr>
<td>0.00 -0.67 -0.71 -0.83 -1.33 -1.60 -2.40 -3.20 -2.00</td>
<td></td>
</tr>
<tr>
<td><strong>SPI</strong> = ES/AT</td>
<td></td>
</tr>
<tr>
<td>0 0.33 0.64 0.72 0.67 0.68 0.60 0.54 0.75</td>
<td></td>
</tr>
<tr>
<td><strong>Sum ES</strong> = SV = AT</td>
<td></td>
</tr>
<tr>
<td>0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00</td>
<td></td>
</tr>
<tr>
<td><strong>Check of ES &amp; SV</strong></td>
<td></td>
</tr>
<tr>
<td>0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00</td>
<td></td>
</tr>
</tbody>
</table>
Thankyou for your Attention

L&A Pressure Welding Pty Ltd