Project Duration Forecasting

*a comparison of EVM methods to ES*

Walt Lipke
PMI - Oklahoma City Chapter
+1 405 364 1594
waltlipke@cox.net
www.earnededschedule.com
Abstract

- EVM methods for forecasting project duration are generally accepted practice, yet they have not been well studied as to their predictive capability.
- Using real project data, four EVM methods are examined and compared to the Earned Schedule prediction technique.
Overview

- Introduction
- EVM & ES Duration Forecasting
- Discussion of Methods & Considerations
- Study Hypothesis & Methodology
- Data Description
- Results & Analysis
- Summary & Conclusions
Introduction

- Earned Schedule introduced in 2003
  - Time-based indicators for schedule
- ES extended to duration forecasting in 2004
- Two efforts explored the capability of ES forecasting
  - Case study of US Navy project
  - Comprehensive examination of two EVM-based methods and ES using simulation
Introduction

- “The results confirm that the ES method outperforms, on average, the other forecasting methods” - Vanhoucke & Vandevoorde

- Results are supportive of ES, but there are lingering questions
  - Does simulation, albeit comprehensive, truly represent real project circumstances?
  - Is broad validation possible from the single case study and other sporadic application results?
Introduction

- Results for ES have been studied to some degree …but traditional EVM forecasting methods have not.
- To bridge these gaps, the forecasting capabilities of four EVM duration forecasting methods are compared to the results for ES using data from 16 projects.
EVM & ES Duration Forecasting

- Four EVM duration forecasting techniques have been commonly applied for 40 years
- The EVM methods have the basic form
  - \( \text{Duration Forecast} = \text{Elapsed Time} \)
  - \( + \text{Forecast for Work Remaining} \)
  - \( \text{IEAC}(t) = AT + (BAC - EV) / \text{Work Rate} \)

- Four Work Rates –
  - Average Planned Value: \( PVav = PVcum / n \)
  - Average Earned Value: \( EVav = EVcum / n \)
  - Current Period Planned Value: \( PVlp \)
  - Current Period Earned Value: \( EVlp \)
The ES idea is to determine the time at which the EV accrued should have occurred.

Time based schedule performance efficiency: \( \text{SPI}(t) = \frac{\text{ES}}{\text{AT}} \)
EVM & ES Duration Forecasting

- Final cost forecast from EVM –
  - $IEAC = \frac{BAC}{CPI}$

- Similarly final duration is forecast using ES –
  - $IEAC(t) = \frac{PD}{SPI(t)}$
  - *where PD is the planned duration of the project*
Methods & Considerations

- The EVM methods have mathematical failings
- When a project executes past its planned duration –
  - PVcum = BAC and increases no further
  - PVav = BAC / m …where m is larger than N, the number of periods of the plan
  - As m increases, PVav decreases causing forecast for work remaining to be longer than its planned time
Methods & Considerations

- When a project executes past its planned duration –
  - For PVlp no periodic values exist beyond the PD
  - Calculation of IEAC(t) is indeterminate
  - These periods are excluded from the analysis …the earlier forecasts may be good
  - Desire is to allow each method to show well, despite its limitations
Methods & Considerations

- Work rates, EVav and EVlp, normally do not have indeterminate conditions.
- One exception – *small projects assessing status weekly* – may have periods for which no EV is accrued.
  - When this occurs, EVlp = 0 and the associated IEAC(t) is indeterminate.
  - Indeterminate condition is accommodated by using previous valid observation.
Methods & Considerations

- Forecasting using ES does not experience indeterminate calculation conditions.
- With exception for the forecast using PVlp, all forecasting calculation methods studied converge to the actual final duration.
Study Hypothesis & Methodology

- The Earned Schedule method for forecasting final duration is believed to be better than the four traditional EVM methods.
- The test for the conjecture is constructed to show that the aggregate of the EVM methods produce better forecasts than does ES.
  - If EVM methods prove superior, further examination is necessary to identify which method is applicable for a set of conditions.
Study Hypothesis & Methodology

- The hypothesis is formally defined as
  - **Ho**: EVM methods produce the better forecast of final project duration
  - **Ha**: ES method produces the better forecast of final project duration

- Ho is termed in the jargon of statistics as the “null hypothesis” …it is the statement to be validated
- Ha is the alternate hypothesis
Study Hypothesis & Methodology

- The statistical testing is performed using the Sign Test applied at 0.05 level of significance.
- Assuming each method has an equal probability of success, the probability for each trial is 0.8.
- The test statistic for the hypothesis test is computed from the number of times the EVM methods yield the better forecast.
  - With 16 projects, the maximum number of successful trials is 16.
  - When EVM successes are fewer than 10, the test statistic value is in the critical region ...there is enough evidence to reject the null hypothesis.
Study Hypothesis & Methodology

- The test statistic is determined from the ranking of the standard deviation for each of the five methods
  - Standard deviation is computed from the variation between forecast values and the actual final duration
  - Smallest standard deviation is ranked “1”
    …largest is “5”
  - Number of times the EVM methods are ranked “1” without ties determines the test statistic value
  - The ranking approach normalizes the differences in time units between projects
Study Hypothesis & Methodology

- To better understand and distinguish between forecasting methods, the projects are tested and analyzed for seven performance regions:
  - Early – 10% to 40% complete
  - Middle – 40% to 70% complete
  - Late – 70% to 100% complete
  - Overall – 10% to 100% complete
  - Converge Early – 25% to 100%
  - Converge Middle – 50% to 100%
  - Converge Late – 75% to 100%
Data Description

- Data from 16 projects are used in the testing and analysis ... 12 high tech and 4 IT
- High tech projects have monthly periods while the IT projects were measured weekly
- Two projects completed early, three on time and eleven were late – *none had re-plans*

<table>
<thead>
<tr>
<th>Project</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Duration</td>
<td>21m</td>
<td>32m</td>
<td>36m</td>
<td>43m</td>
<td>24m</td>
<td>50m</td>
<td>46m</td>
<td>29m</td>
</tr>
<tr>
<td>Actual Duration</td>
<td>24m</td>
<td>38m</td>
<td>43m</td>
<td>47m</td>
<td>24m</td>
<td>59m</td>
<td>54m</td>
<td>30m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Duration</td>
<td>45m</td>
<td>44m</td>
<td>17m</td>
<td>50m</td>
<td>81w</td>
<td>25w</td>
<td>25w</td>
<td>19w</td>
</tr>
<tr>
<td>Actual Duration</td>
<td>55m</td>
<td>50m</td>
<td>23m</td>
<td>50m</td>
<td>83w</td>
<td>25w</td>
<td>22w</td>
<td>13w</td>
</tr>
</tbody>
</table>

Legend: m = month  w = week
Results & Analysis

- The graph below is an example of the performance of all five forecasting methods along with a plot of the actual final duration.

Final Duration Forecasting Comparisons

Project #13

<table>
<thead>
<tr>
<th>Method</th>
<th>Line Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEAC(t) - PVav</td>
<td>Red</td>
</tr>
<tr>
<td>IEAC(t) - EVav</td>
<td>Blue</td>
</tr>
<tr>
<td>IEAC(t) - PVlp</td>
<td>Green</td>
</tr>
<tr>
<td>IEAC(t) - EVlp</td>
<td>Yellow</td>
</tr>
<tr>
<td>IEAC(t)es</td>
<td>Pink</td>
</tr>
<tr>
<td>Final</td>
<td>Purple</td>
</tr>
</tbody>
</table>
Results & Analysis

- Forecast characteristics observed –
  - PVlp and EVlp work rates produce volatile results
  - PVav and EVav work rates are smoother
  - ES forecast is much better, especially after 40% complete …after 60% the forecast is very close to the final duration
Final Duration Forecasting Comparisons

Project #13

IEAC(t) - PVav
IEAC(t) - EVav
IEAC(t) - PVlp
IEAC(t) - EVlp
IEAC(t)es
Final
Results & Analysis

- The plot of standard deviation amplifies the view of the final duration comparisons

**Time Forecasting Std Dev Comparisons**

*Project #13*

![Graph showing time forecasting standard deviation comparisons for different variables: PVav Var, EVav Var, PVlp Var, EVlp Var, ES Var. The x-axis represents percent complete ranging from 0% to 100%, and the y-axis represents standard deviation ranging from 0 to 10. Each variable is represented by a different color on the graph.]*
Results & Analysis

- The column graph of the project data more clearly illustrates the behavior for early, middle, late and overall groupings.

Comparison of Forecasting Accuracy

Project #13

<table>
<thead>
<tr>
<th>Percent Complete</th>
<th>10% - 40%</th>
<th>40% - 70%</th>
<th>70% - 100%</th>
<th>10% - 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVav Var</td>
<td>10.6</td>
<td>12.3</td>
<td>15.9</td>
<td>16.4</td>
</tr>
<tr>
<td>EVav Var</td>
<td>22.8</td>
<td>15.9</td>
<td>16.2</td>
<td>16.4</td>
</tr>
<tr>
<td>PVlp Var</td>
<td>28.3</td>
<td>14.8</td>
<td>16.2</td>
<td>14.2</td>
</tr>
<tr>
<td>EVlp Var</td>
<td>33.6</td>
<td>40.8</td>
<td>24.1</td>
<td>23.1</td>
</tr>
<tr>
<td>ES Var</td>
<td>40.8</td>
<td>40.8</td>
<td>24.1</td>
<td>23.1</td>
</tr>
</tbody>
</table>

Standard Deviation

10% - 40% 40% - 70% 70% - 100% 10% - 100%

PVav Var EVav Var PVlp Var EVlp Var ES Var
The column graph assists examination of convergence characteristic.

**Comparison of Forecasting Convergence**

**Project #13**

<table>
<thead>
<tr>
<th>Percent Complete</th>
<th>PVav Var</th>
<th>EVav Var</th>
<th>PVlp Var</th>
<th>EVlp Var</th>
<th>ES Var</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% - 100%</td>
<td>14.2</td>
<td>16.4</td>
<td>27.7</td>
<td>23.1</td>
<td>30.0</td>
</tr>
<tr>
<td>25% - 100%</td>
<td>14.4</td>
<td>13.8</td>
<td>22.4</td>
<td>26.3</td>
<td>15.2</td>
</tr>
<tr>
<td>50% - 100%</td>
<td>15.3</td>
<td>15.2</td>
<td>17.3</td>
<td>23.3</td>
<td>15.8</td>
</tr>
<tr>
<td>75% - 100%</td>
<td>15.8</td>
<td>15.8</td>
<td>15.6</td>
<td>23.9</td>
<td>15.6</td>
</tr>
</tbody>
</table>

Standard Deviation

**Notes:**
- PVav Var, EVav Var, PVlp Var, EVlp Var, ES Var represent different forecasting variables.
- The graph compares the percentage complete across different standard deviation intervals.
Results & Analysis

- The column graphs indicate, as expected, that the current period forecasting methods, EVlp & PVlp, produce more volatile results.

- For the project depicted, the ES forecast is the superior predictor in every range examined.

- The expectation of decreasing standard deviation as the percent complete range is increasingly focused toward completion is observed for ES and EVlp, only.

  - The characteristic is seen for PVav & EVav …but is not strongly evident until after 80% complete (refer to line graphs).
Results & Analysis

- Below is an example of the compilation of the standard deviations and rankings for the 10% - 40% grouping

<table>
<thead>
<tr>
<th>Project ID</th>
<th>Project #1</th>
<th>Project #2</th>
<th>Project #3</th>
<th>Project #4</th>
<th>Project #5</th>
<th>Project #6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
</tr>
<tr>
<td>PVav</td>
<td>14.95</td>
<td>5</td>
<td>13.01</td>
<td>4</td>
<td>11.93</td>
<td>2</td>
</tr>
<tr>
<td>EVav</td>
<td>2.65</td>
<td>1</td>
<td>9.35</td>
<td>2</td>
<td>8.28</td>
<td>1</td>
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<tr>
<td>PVlp</td>
<td>5.47</td>
<td>2</td>
<td>13.62</td>
<td>5</td>
<td>77.74</td>
<td>5</td>
</tr>
<tr>
<td>EVlp</td>
<td>6.00</td>
<td>3</td>
<td>12.14</td>
<td>3</td>
<td>22.38</td>
<td>3</td>
</tr>
<tr>
<td>ES</td>
<td>8.28</td>
<td>4</td>
<td>4.78</td>
<td>1</td>
<td>46.76</td>
<td>4</td>
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<table>
<thead>
<tr>
<th>Project ID</th>
<th>Project #7</th>
<th>Project #8</th>
<th>Project #9</th>
<th>Project #10</th>
<th>Project #11</th>
<th>Project #12</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
</tr>
<tr>
<td>PVav</td>
<td>9.79</td>
<td>3</td>
<td>16.16</td>
<td>3</td>
<td>6.75</td>
<td>2</td>
</tr>
<tr>
<td>EVav</td>
<td>6.00</td>
<td>2</td>
<td>33.17</td>
<td>5</td>
<td>15.63</td>
<td>3</td>
</tr>
<tr>
<td>PVlp</td>
<td>17.95</td>
<td>5</td>
<td>20.69</td>
<td>4</td>
<td>20.80</td>
<td>4</td>
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<tr>
<td>EVlp</td>
<td>15.07</td>
<td>4</td>
<td>5.69</td>
<td>2</td>
<td>52.62</td>
<td>5</td>
</tr>
<tr>
<td>ES</td>
<td>4.31</td>
<td>1</td>
<td>5.09</td>
<td>1</td>
<td>3.74</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project ID</th>
<th>Project #13</th>
<th>Project #14</th>
<th>Project #15</th>
<th>Project #16</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
<td>Proj Std Dev</td>
<td>Proj Rank</td>
</tr>
<tr>
<td>PVav</td>
<td>10.57</td>
<td>2</td>
<td>2.36</td>
<td>1</td>
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<tr>
<td>EVav</td>
<td>22.78</td>
<td>3</td>
<td>5.90</td>
<td>5</td>
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<tr>
<td>PVlp</td>
<td>28.25</td>
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<td>2.36</td>
<td>1</td>
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<tr>
<td>EVlp</td>
<td>33.59</td>
<td>5</td>
<td>5.49</td>
<td>4</td>
</tr>
<tr>
<td>ES</td>
<td>8.62</td>
<td>1</td>
<td>4.46</td>
<td>3</td>
</tr>
</tbody>
</table>
Results & Analysis

- For the table shown, the rank for the ES method is “1” for eleven projects ... a large majority ... even so, we see that the ES forecast is not best for every project.

- Every range is examined in the same way ... to have a more complete understanding of how the various forecasting methods perform under differing circumstances.
Results & Analysis

- To more clearly understand the performance of the 5 forecasting methods, the ranking results are condensed into tables for each data grouping...below is an example.

- The distribution of results are used to compute a weighted average for assessing the overall performance for each method.

### Rank Count for Data Group 10% - 40%

<table>
<thead>
<tr>
<th>Count</th>
<th>Methods</th>
<th>PVav</th>
<th>EVav</th>
<th>PVlp</th>
<th>EVlp</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr 1s</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Nr 2s</td>
<td></td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Nr 3s</td>
<td></td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Nr 4s</td>
<td></td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Nr 5s</td>
<td></td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

| Weighted Average | 2.750 | 3.250 | 3.375 | 3.875 | 1.688 |
| Composite Rank   | 2     | 3     | 4     | 5     | 1     |
Results & Analysis

- Displayed below is a tabulation of the weighted averages of the rankings for all data ranges examined.
- The ES method has the lowest value for every range. Only the PVav method is close for the 40% - 70% data grouping.

<table>
<thead>
<tr>
<th>Percent Complete Test Bands</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>ES</td>
<td>1.688</td>
<td>2.063</td>
<td>1.438</td>
<td>1.625</td>
<td>1.563</td>
<td>1.563</td>
<td>1.438</td>
</tr>
<tr>
<td>PVav</td>
<td>2.750</td>
<td>2.500</td>
<td>3.688</td>
<td>2.625</td>
<td>2.813</td>
<td>3.063</td>
<td>3.875</td>
</tr>
<tr>
<td>EVav</td>
<td>3.250</td>
<td>2.813</td>
<td>2.938</td>
<td>3.000</td>
<td>3.063</td>
<td>2.938</td>
<td>2.875</td>
</tr>
<tr>
<td>EVlp</td>
<td>3.875</td>
<td>4.188</td>
<td>3.063</td>
<td>3.938</td>
<td>3.688</td>
<td>3.750</td>
<td>2.938</td>
</tr>
</tbody>
</table>
Results & Analysis

- The results of the statistical hypothesis testing is compiled in the table below.
- With the exception of the 40% - 70% range, the ES method is clearly superior to the EVM methods combined ...the test statistic is in the critical region, thereby rejecting the Ho hypothesis.
- The ES method is shown to be the better forecasting method, regardless of project completion stage.

<table>
<thead>
<tr>
<th>Significance</th>
<th>Percent Complete Test Bands</th>
</tr>
</thead>
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<tr>
<td><strong>0.05</strong></td>
<td>10% - 40%</td>
</tr>
<tr>
<td>Test Statistic</td>
<td><strong>0.0000</strong></td>
</tr>
<tr>
<td>Sign Test</td>
<td>Ha</td>
</tr>
<tr>
<td>Count</td>
<td>ES</td>
</tr>
<tr>
<td>#1s</td>
<td>EVM</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
Summary

- Four traditional EVM forecasting methods were examined and compared to the ES technique.
- Data from 16 projects was used to examine the performance of the 5 forecasting methods.
- Seven ranges of percent complete were applied to isolate forecasting characteristics or tendencies.
- The standard deviation from the actual final duration was used to evaluate forecasting performance.
Summary

- Forecasting performance for each project was ranked from best to worst for the seven ranges of project completion.
- The weighted averages of the rankings were used to evaluate goodness of performance.
- Hypothesis testing of the best forecasts for each completion range was evaluated.
Conclusions

- The weighted average of rankings indicate ES is a better predictor of final duration than any of the EVM methods
  - The PVav method showed to be close, but slightly worse than the ES technique for the 40% - 70% project completion range
- The hypothesis testing of best forecast yielded identical results to the weighted rankings

For every range of data grouping the ES forecast is identified as the better predictor of final duration
Acknowledgement

- Project data was made available by –
  - Dr. Ofer Zwikael
    Professor of Business
    Australian National University
  - Kym Henderson
    IT Project Manager
    Sydney, AU
References

- Earned Schedule Website: [www.earnedschedule.com](http://www.earnedschedule.com)