Earned Schedule – Ten Years After[1]

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Abstract

Earned Schedule is an extension to Earned Value Management. The method provides considerable capability to project managers for analysis of schedule performance. From the time of the public's first view of Earned Schedule with the publication of "Schedule is Different" in the March 2003 issue of The Measurable News, its propagation and uptake around the world has been extraordinary. This article will cover the capabilities of the method and challenges encountered, progressing through the significant extensions, to its present status.

Origin of Earned Schedule

This is the ten year anniversary of Earned Schedule (ES). During its relatively short existence, ES has made a large impact on Earned Value Management (EVM) and project management, as well. Frankly, I have been extremely surprised by its uptake in EVM application and academia, including research.

In my keynote at the recent EVM World conference, I recounted the story of how ES came about. In 2002, I was involved with software process improvement in an organization that had nearly achieved Level 5 of the Software Engineering Institute Capability Maturity Model (SEI CMM®). Only one Key Process Area, Defect Prevention (DP), remained to satisfy the achievement of Level 5.

Software organizations were attempting to satisfy DP by applying Statistical Process Control (SPC) to defect counts from the quality process of software development, i.e. inspections and reviews. My belief was that this approach to achieve DP could possibly cause sub-optimization of the development process. This later was shown to be true.

My thought was to use management indicators that encompassed most of the development process. By encompassing the process, the improvement would more generally be beneficial and more likely have positive impact. We were employing EVM; thus, it seemed reasonable to apply SPC to the cost and schedule performance indexes, CPI and SPI, respectively. After all, EVM was used in the project execution phase, generally eighty percent of the effort.

Before much action was taken to investigate this approach, I attended the College of Performance Management (CPM) 2002 spring conference, at which a presentation was given by Quentin Fleming. In his presentation the statistics based research of CPI by Dr. Christensen was discussed. It was fascinating material, and due to the statistical nature of the research it led me to believe I was on the right track with using CPI to satisfy the DP attribute of the

[1] Second Editions are previously published papers that have continued relevance in today's project management world, or which were originally published in conference proceedings or in a language other than English. Original publication acknowledged; authors retain copyright. This paper was based on Mr. Lipke's keynote presentation at the EVM World 2013 conference in May 2013 and originally published in *The Measurable News* in August 2013. It is republished here with the author's permission.

CMM®. However, later that evening after some reflection, I realized Mr. Fleming did not mention anything about SPI.

The next morning as I walked through the courtyard of the hotel, I happened to encounter Mr. Fleming, with his suitcase, on his way to checkout and leave the conference. I told him I had attended his presentation and that I was really interested in the statistical testing and study of CPI behavior. I then asked, "Has any comparable research been accomplished for SPI?" Mr. Fleming responded saying, "No there hasn't. You do know that SPI fails for late performing projects." …Yes, I knew that, but sometimes you just don't make the connection. It was then obvious, with the known failure mode of SPI, reliable statistical analysis of the indicator was not possible and therefore the SEI CMM® Level 5 key process area, Defect Prevention, could not be satisfied using the SPI indicator.

This was my dilemma. I needed a reliable schedule indicator for software process improvement; thus, the impetus for creating ES. Originally, ES had a single purpose; i.e., provide a path for achievement of CMM® Level 5. There was no intention for ES to be made available to other EVM practitioners. Only after the schedule indicators from ES proved reliable from several months of prototyping on software projects did I realize that the method held potential for the EVM community. This led to the publication of *The Measurable News* article "Schedule Is Different" [Lipke, 2003].

Theory and Capabilities

The fundamental concept of ES is shown in figure 1. As the description reads, "The idea is to determine the time at which the earned value (EV) accrued should have occurred." The time duration associated with the point on the Performance Measurement Baseline (PMB) where planned value (PV) is equal to EV is Earned Schedule.[2] For the EV accrued, ES provides a measure of how much has been earned of the planned duration (PD) of the project.

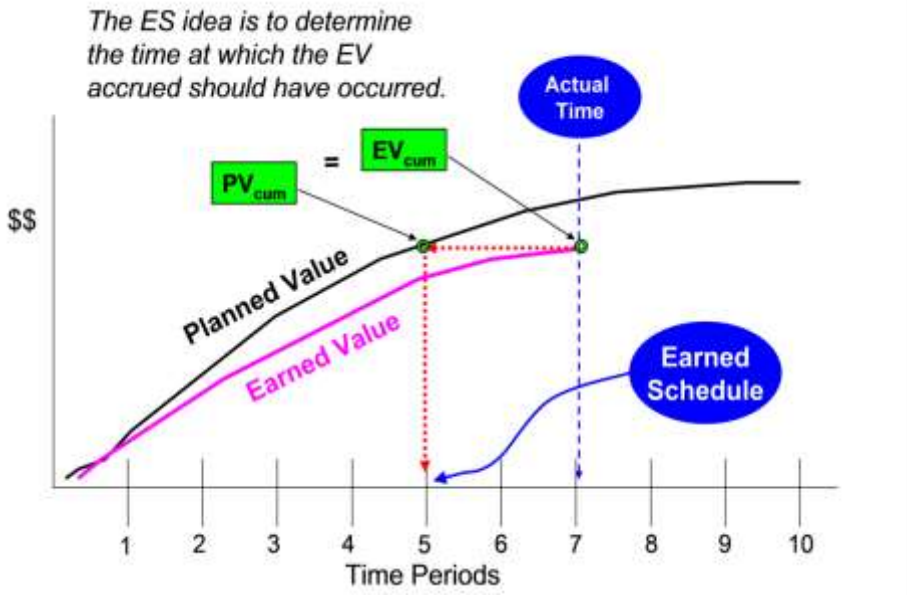

Figure 1. Earned Schedule Concept

[2] For the definitions of PMB, EV, and PV, refer to the *Practice Standard for Earned Value Management* [PMI, 2011].

ES is computed from the simple formula:

$$ES = C + I$$

C is determined by comparing EV to the periodic values for PV, i.e., PV_n. C is the largest value of n satisfying the condition, $EV \geq PV_n$. I is an interpolation using the equation:

$$I = (EV - PV_C) / (PV_{C+1} - PV_C)$$

Indicators

Having ES, the time based schedule indicators are formed, Schedule Variance (time) and Schedule Performance Index (time), abbreviated as SV(t) and SPI(t), respectively. The indicators are computed using the following formulas:

$$SV(t) = ES - AT$$
$$SPI(t) = ES / AT$$

where AT is the actual time, i.e. the duration from the start of the project to the time at which EV is measured.

These indicators perform reliably for both late and early performing projects, whereas the EVM schedule indictors fail for late performing projects, as Mr. Fleming related. Furthermore, the time-based indicators always converge to the actual result at project conclusion.

Forecasting

The SPI(t) indicator has made forecasting duration possible from EVM performance data, using the simple formula [Henderson, 2004]:

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

where IEAC(t) is Independent Estimate at Completion (time-based)

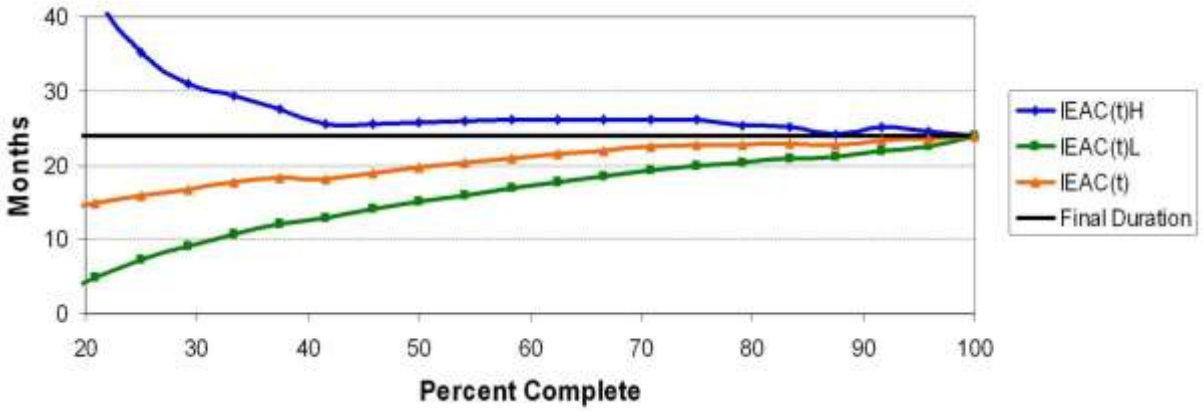

Figure 2. Statistical Forecasting

From this basic forecasting, very powerful statistical forecasting has evolved. In figure 2 the nominal forecast is the graphed line in the middle. The upper and lower lines are Confidence Limits, determined from SPI(t), variation in the periodic values of SPI(t), and a choice of Confidence Level, usually 90 or 95 percent.[3] For the figure, there is a 90 percent probability that the final duration will occur somewhere between the upper and lower graphed lines. As the project progresses, it is observed that the spacing of the two lines narrows, and that they converge along with the nominal forecast to the actual duration.

Prediction

For cost analysis, EVM has the To Complete Performance Index (TCPI), an indicator describing the performance efficiency needed for the remainder of the project to meet a specific cost objective. Until ES, a comparable indicator did not exist for schedule analysis.

ES facilitates the creation of the To Complete Schedule Performance Index (TSPI), formulated as follows:

$$TSPI = (PD - ES) / (ED - AT)$$

where ED is the estimated or desired project duration.

As with TCPI, TSPI can be computed for any desired completion objective. For schedule the durations of interest are, generally, PD and the duration to the customer, derived from the product delivery date.

A useful quality of both TCPI and TSPI is that they provide information concerning whether the project objective is achievable and whether a poor performing project is recoverable [Lipke, 2009]. Discrete TSPI values provide management with decision information:

$TSPI \leq 1.00$	Duration objective is achievable
$TSPI > 1.10$	Duration objective is unachievable
$1.00 < TSPI \leq 1.10$	Recovery may be possible

Either TCPI or TSPI can be formulated such that it is dependent upon two variables, the performance index at a specific status point and the fraction complete. For schedule analysis, the formulation is:

$$TSPI = (1 - K) / (R - K/SPI(t))$$

where $K = ES/PD$ and $R = ED/PD$

This formulation provides the project manager (PM) with the ability to "look ahead." For the specific duration objective, the PM can determine when the project becomes unrecoverable and the time available for a corrective management intervention.

[3] The terms, Confidence Limits and Confidence Level, come from the mathematics of statistics. To fully define them and the calculation methods for this application is beyond the scope of the article. The reader, if interested in having a greater understanding, is referred to my book, *Earned Schedule* [Lipke, 2009].

Critical Path

Especially for large projects, analysis of Critical Path (CP) performance is aligned with schedule experts, segregated from the EVM analysts. ES provides a method using EVM data to assess CP performance, thereby providing an alternative and cross-check to the schedulers' assessment [Lipke, 2009].

The technique treats the CP as a separate project. The PMB for the CP is created from the PV in its tasks. Then, using the EV accrued within the CP tasks, ES for CP performance is computed. Continuing, SV(t), SPI(t), and IEAC(t) can be determined for the CP.

The CP values for the indicators and forecast are then used for comparison to the schedulers' assessment. As well, additional management information is available from the comparison of the CP computed values to the ES analysis for the total project. Inconsistency in compared values is cause for deeper analysis.

From reported application, the forecast from the schedulers' CP analysis is consistently optimistic because it does not account for the current schedule performance efficiency. The schedulers' method adds the schedule variance of the completed work to the planned duration, expecting the remaining work to be performed as planned. Because the ES method accounts for efficiency, EVM analysts have indicated earlier identification of CP performance issues.

Schedule Adherence

The schedule is an embodiment of our best understanding of how to accomplish the project. It follows then that the planned schedule is crucial to project success, and that project managers should do their utmost to ensure project execution conforms to it. The planned schedule is the most efficient path for executing the project; any deviation leads to inefficiency and very likely other problems ….such as constraint reduced production, idle time, skills mismatch and poor quality output, in turn, requiring rework. Therefore, it is not enough to have knowledge of the execution efficiency, SPI(t). Additionally, project managers (PM) need to know how well the process is being followed.

ES provides the capability to determine whether the accomplishment is in agreement with the expectation from the planned schedule [Lipke, 2009]. The value of ES identifies the PV which should have been accomplished in every task. By matching the EV accrued to PV expectation, an indicator of schedule adherence (SA) is formed, termed the P-Factor. When matching is perfect, P equals 1.00 and when there is no correlation, P is 0.00. As the project progresses P tends to increase, concluding at the value 1.00 at completion.

The concept of SA, along with the P-Factor, facilitates very useful analysis. Tasks are pinpointed which may have constraints or impediments hindering project accomplishment. With this information, management has the opportunity to investigate and remove the hindrances. As well, tasks having the potential for future rework are identified. Significantly, the value for project rework can be forecast, thereby providing management with the potential cost impact from the lack of schedule adherence.

Discontinuous Performance

There are conditions during project execution, generally for small, short duration projects, that can cause error in the calculated values for the ES indicators and duration forecasts. These conditions are the following:

1) *Down Time* – periods of performance in which no work has been planned or scheduled

2) *Stop Work* – periods during execution where management has halted performance

ES calculation methods have been developed to accommodate these conditions [Lipke, 2011]. Without the methods, the distorted indicator and forecast values have the potential to cause unneeded and possibly erroneous management action. The ES calculation methods addressing Down Time/Stop Work have been shown to yield improved indicators and forecasts. Improvement is seen in both accuracy and rate of convergence to the actual result.

Longest Path

Research performed by Dr. Mario Vanhoucke has shown that ES forecasting performs best when the topology of the network schedule is serial [Vanhoucke, 2009]. Furthermore, as the network topology becomes more parallel, the research indicates that the forecast values are less reliable.

The most recent evolution of ES forecasting was created to utilize the serial topology research finding. For this methodology, all of the serial paths to completion in the schedule network are identified. For each a PMB is created and used for forecasting, similarly to the method described earlier for CP analysis. The serial path having the longest duration forecast is theorized to best represent the project.

Figure 3 illustrates the comparison of forecasts, the normal to longest path (LP). The visual supports the improvement expectation in ES forecasting provided by LP. As observed, the variation of the LP forecast is reasonably uniform around the actual duration, whereas the total project forecast has much more variation in converging to the actual duration.

The results from the notional data example are compelling. However, they are insufficient to say LP forecasting should be adopted and employed without further examination and testing. I am hopeful, with additional confirmation and tools for applying LP, the methodology will provide significant improvement of ES forecasting for network schedules whose topology is highly parallel.

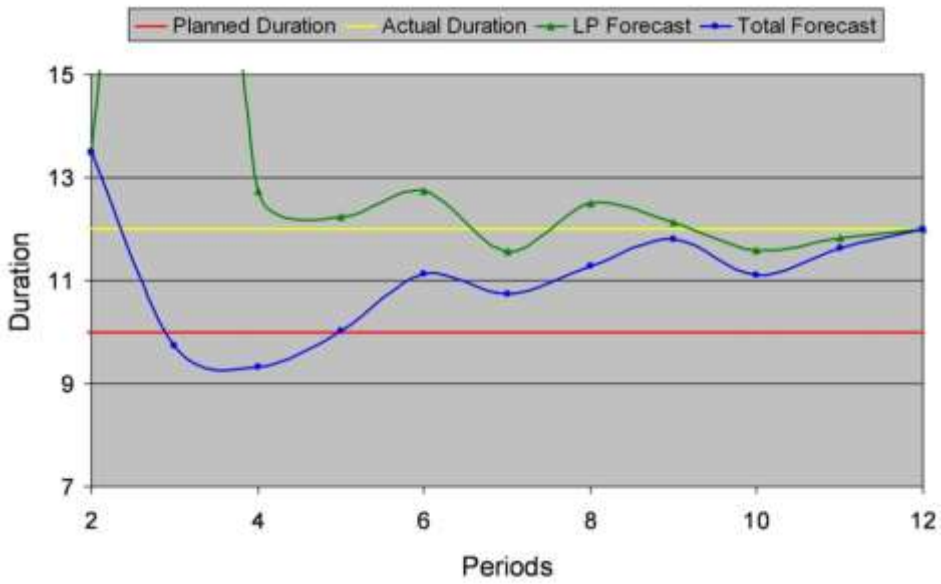

Figure 3. Longest Path Forecasting

Challenges

Although ES has become well accepted, it has not always been. After the seminal paper, "Schedule is Different" and the subsequent paper, "Earned Schedule: A Breakthrough Extension to Earned Value Theory?," by Kym Henderson [Henderson, 2003] were published, an over exuberance developed. There was even some discussion favoring replacement of the EVM schedule indicators with those from ES, SV(t) and SPI(t). The exuberance was quelled; however, an insert to the *PMI Practice Standard for EVM, 1st edition*, was created to generate awareness of ES and to gain feedback from trial applications [PMI, 2005].[4]

From that beginning serious resistance to ES developed. Possibly, the initial rejection came from a view that Kym and I had little credibility in the EVM community. From their perspective, we had limited EVM experience and were new members of CPM. Some ridiculed the method and its advocates from the long held position that the only way to perform schedule performance analysis is to directly employ the schedule. Others added the quizzical argument, stating that although EVM has indicators with "schedule" in their description, they were never intended to be used for schedule performance analysis. A few, in the extreme, used intimidation tactics to discourage the use and propagation of ES.

Next came the questioning of the mathematics of the ES calculation. Although the description of the calculation method was made in the seminal article, including application examples, there were assertions that ES is an interpolation made from the linearization of the entire PMB. Of course, it is not. ES does use linear interpolation, but only for a single performance period. After the initial flurry of discussion, the misinterpretation of the ES calculation appears to be resolved. It has not reappeared in several years.

Presently, there remains skepticism about ES, most likely connected to resistance to change. Rigidity is a difficult obstacle to overcome. Logic and reasoning are set aside while opinion, emotion, and political power become the position determinants.

This residual skepticism affects whether ES is accepted by the EVM community and fully incorporated into the EVM practice. Across the globe, there is considerable evidence of increased application of ES, indicating its general acceptance. An eventual preponderance of usage may overcome the skeptics; only time will tell whether ES is adopted.

Affirmation

Significantly, Kym Henderson's article verified the performance of the ES indicators from application to real data [Henderson, 2003]. Several advantages were cited for ES:

1) Simplicity of the calculations
2) Time-based indicators as opposed to the cost-based EVM indicators
3) No additional data required
4) Indicators perform reliably for either early or late performing projects
5) Indicator values converge and resolve to the actual project result

In his article, Mr. Henderson summarized the examination of ES, saying:

[4] The insert was authored by Dr. John Singley and Eleanor Haupt of the College of Performance Management.

"The retrospective analysis of ES using my own EVM projects' data, … has confirmed with remarkable precision the accuracy of the ES concept and ES metrics …when compared to their historic EVM counterparts."

As well, other independent successful trials of the ES method were subsequently reported, most notably is one at Lockheed Martin conducted by Robert Handshuh. Additional to the trials, research was performed which confirmed the performance of ES. Dr. Mario Vanhoucke and Stephan Vandevoorde using methods of simulation compared ES to other EVM based methods of duration forecasting [Vanhoucke, et al., 2007]. They formed the conclusion:

"The results reveal that the earned schedule method outperforms, on the average, all other forecasting methods."

Most recently, Captain Kevin Crumrine and Lieutenant Colonel Jonathon Ritschel of the USAF, using EVM data from 64 major defense projects, examined performance of the schedule indicators from EVM and ES [Crumrine, et al., 2013]. Crumrine and Ritshcel made the comparison using statistical hypothesis testing methods. Their conclusion, with regard to the schedule indicators from each methodology, was made as follows:

"This research finds Earned Schedule to be a more timely and accurate predictor than Earned Value Management."

Affirmation of ES is noted in several other venues, as well:

1) Positive feedback from application globally
2) Incorporation into EVM analysis tools – EV Engine, IPM Pro, Visi Trend, ProTrack, and Project Flight Deck
3) Inclusion in EVM training from various sources
4) Inclusion in project management coursework at several universities globally
5) Appearance in project management textbooks
6) As a topic of interest in several published research articles (academic journals, occurring globally)

Resources

For those using ES or those who want to begin, there are several resources available. The one, perhaps of the greatest value, is the ES website, www.earnedschedule.com. The website has a considerable amount of material, including news, publications, presentations, calculators, and much more. With very few exceptions the materials are free for download and individual use.

The website began in February 2006. In that first month it received approximately 6000 "hits." The website has become increasingly more popular and is now receiving approximately 55,000 hits per month, and recently had a count of over 63,000.

Another good source for ES material is the PMI EVM practice standard [PMI, 2011]. The standard includes Appendix D, Schedule Analysis Using EVM Data, which predominantly is a description of ES. And of course my book, *Earned Schedule*, is available.

Wrap Up

ES facilitates considerable schedule performance analysis capability from EVM data. The capabilities offered by ES – time-based indicators, duration forecasting, prediction, critical path, schedule adherence, constraint/impediment identification, rework cost, discontinuous performance, and schedule network topology – previously were not believed possible.

It is my opinion that acceptance of ES should help to popularize EVM. With the inclusion of ES, EVM can make the case that, now, in a single method, project cost and schedule can be managed.

Even without full acceptance the impact of ES can no longer be ignored. It is being used world-wide in many venues - large and small projects, and in academia, as well.

Acknowledgement

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Recommendation

Earned Schedule has endured for ten years. ES has proven itself through application, prototyping, and testing in real and simulated environments. It is propagating world-wide in use, in academic coursework and research. I believe it is time for ES to be normalized to EVM. ES needs to be integrated into EVM guidance; it should become a normal component of EVM training; and, ES capability should be commonplace for EVM analysis tools.

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About the Author

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Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base. He has over 35 years of experience in the development, maintenance, and management of software for automated testing of avionics. During his tenure, the division achieved several software process improvement milestones, including the coveted SEI/IEEE award for Software Process Achievement. Mr. Lipke has published several articles and presented at conferences, internationally, on the benefits of software process improvement and the application of earned value management and statistical methods to software projects. He is the creator of the technique *Earned Schedule*, which extracts schedule information from earned value data. Mr. Lipke is a graduate of the USA DoD course for Program Managers. He is a professional engineer with a master's degree in physics, and is a member of the physics honor society, Sigma Pi Sigma (ΣΠΣ). Lipke achieved distinguished academic honors with the selection to Phi Kappa Phi (ΦΚΦ). During 2007 Mr. Lipke received the PMI Metrics Specific Interest Group Scholar Award. Also in 2007, he received the PMI Eric Jenett Award for Project Management Excellence for his leadership role and contribution to project management resulting from his creation of the Earned Schedule method. Mr. Lipke was selected for the 2010 Who's Who in the World. At the 2013 EVM Europe Conference, he received an award in recognition of the creation of Earned Schedule and its influence on project management, EVM, and schedule performance research. Walt can be contacted at waltlipke@cox.net.