Earned Schedule: An Emerging Enhancement to Earned Value Management

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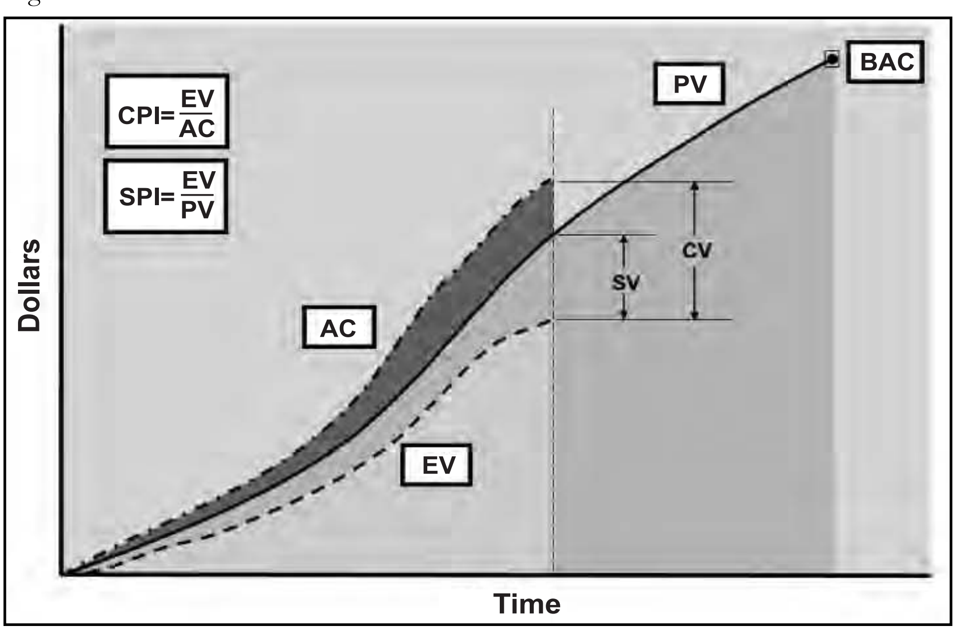
Earned Schedule (ES) is a method of extracting schedule information from Earned Value Management (EVM) data. The method has been shown to provide reliable schedule indicators and predictors for both early and late finish projects. ES is considered a breakthrough technique to integrated performance management and EVM theory and practice. The method has propagated rapidly and is known to be used as a management tool for software, construction, commercial, and defense projects in several countries, including the United States, Australia, United Kingdom, Belgium, and Sweden. The principles of ES have been included in the "Project Management Institute College of Performance Management, Practice Standard for EVM" as an emerging practice [1].

EVM was created within the U.S. Department of Defense in the 1960s and has shown over the four decades from that time to be a very valuable project management and control system. EVM uniquely connects cost, schedule, and requirements thereby allowing for the creation of numerical project performance indicators. Managers now have the capability to express the cost and technical performance of their project in an integrated and understandable way to employees, superiors, and customers.

For all of the accomplishments of EVM in expressing and analyzing cost performance, it has not been as successful for schedule performance. The EVM schedule indicators are, contrary to expectation, reported in units of cost rather than time. And, because cost is the unit of measure, the schedule indicators require a period of familiarization before EVM users and project stakeholders become comfortable with them and their use. Beyond this problem, there is the much more serious issue: The EVM schedule indicators fail for projects executing beyond the planned completion date.

Because these problems are well known to EVM practitioners, over time the application has evolved to become a management method focused primarily on cost. The schedule indicators are available, but are not relied upon to the same extent as the indicators for cost. The resultant project management impact from the EVM schedule indicator issues is cost and schedule analyses of project status and performance have become disconnected. Cost analysts view the EVM cost reports and indicators while schedulers tediously update and analyze the network schedule. Frequently for large projects, these separate skills are segregated and, often, their respective analyses are not reconciled.

Figure 1: *Earned Value*



It has been a long expressed desire by EVM practitioners to have the ability to perform schedule analysis from EVM data similarly to the manner for cost. Various approaches to using earned value (EV) for this analysis have been proposed and studied from time to time. However, none of the methods have proven to be satisfactory for both early and late finishing projects.

Before discussing the ES approach to overcoming the described cost-schedule dilemma, let us first review EVM.

EVM Measures and Indicators

EVM has three measures: planned value (PV), actual cost (AC), and EV. Refer to Figure 1 as an aid to this discussion. The planned values of the tasks comprising the project are summed for the periodic times (e.g., weekly or monthly) chosen to status project performance. The time-phased representation of the planned value is the performance management baseline (PMB). AC and EV are accrued and are likewise associated with the reporting periods. For each measure, the time-phased graphs are characteristically seen to be S-curves. Observe that PV concludes at the Budget at Completion (BAC), the planned cost for the project. The BAC is the total amount of PV to be earned.

From the three measures, project performance indicators are formed. The cost variance (CV) and cost performance index (CPI) are created from the EV and AC measures, as follows: CV = EV - AC and CPI = EV/AC. In a similar manner, the schedule indicators are: SV = EV - PV, and SPI = EV/PV, where SV is the schedule variance and SPI is the schedule performance index.

Now examine the formulation of the schedule indicators and recall that the PV and EV curves conclude at the same value, BAC. The fact that PV equals BAC at the planned completion point and does not change when a project runs late causes the schedule indicators to falsely portray actual performance. In fact, it is commonly observed that the schedule indicators begin this behavior when the project is approximately 65 percent complete.

The irregular behavior of the schedule indicators causes problems for project managers. At some point it becomes obvious when the SV and SPI indicators have lost their management value. But, there is a preceding gray area, when the manager cannot be sure of whether or not he should believe the indicator and subsequently react to it. From this time of uncertainty until project completion, the manager cannot rely on the schedule indicators portion of EVM.

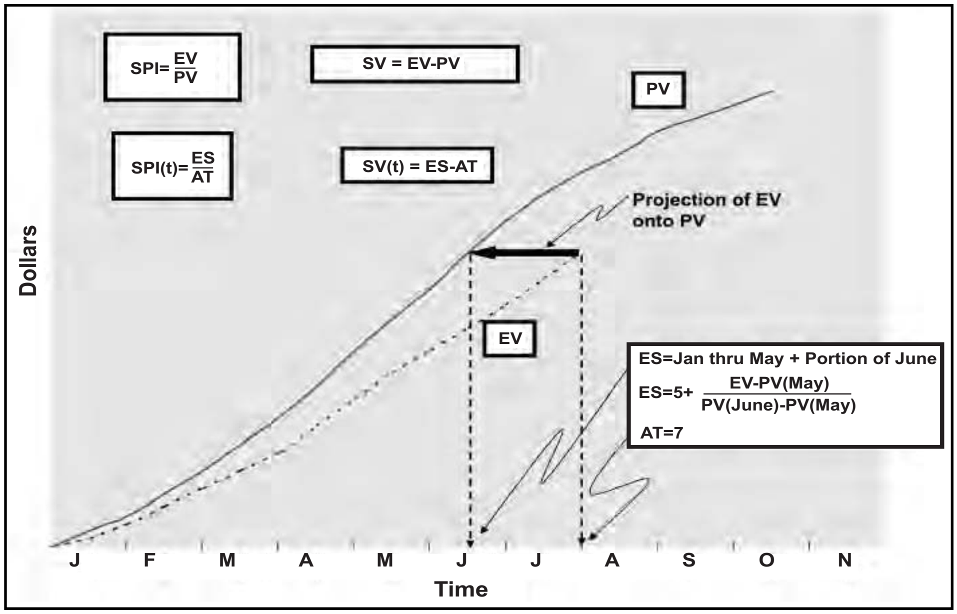


Figure 2: *ES Concept*

Earned Schedule Description

The technique to resolve the problem of the EVM schedule indicators is ES. The ES idea is simple: Identify the time at which the amount of EV accrued should have been earned [2]. By determining this time, time-based indicators can be formed to provide schedule variance and performance efficiency management information.

Figure 2 illustrates how the ES measure is obtained. Projecting the cumulative EV onto the PV curve (i.e., the PMB), as shown by the diagram, determines where PV equals the EV accrued. This intersection point identifies the time that amount of EV should have been earned in accordance with the schedule. The vertical line from the point on the PMB to the time axis determines the *earned* portion of the schedule. The duration from the beginning of the project to the intersection of the time axis is the amount of ES.

With ES determined, it is now possible to compare where the project is timewise with where it should be in accordance with the PMB. *Actual time*, denoted AT, is the duration at which the EV accrued is recorded. The time-based indicators are easily constructed from the two measures, ES and AT. SV becomes SV(t) = ES - AT, and SPI is SPI(t) = ES/AT.

The graphic and the box in the lower right portion of Figure 2 portray how ES is calculated. While ES could be determined graphically as described previously, the concept becomes much more useful when facilitated as a calculation. As observed from Figure 2, all of the PV through May has been earned. However, only a portion of June has been completed with respect to the baseline. Thus the duration of the completed portion of the planned schedule is in excess of five months. The EV accrued appears at the end of July, making actual time equal to seven months. The method of calculation to determine the portion of June to credit to ES is a linear interpolation. The amount of EV extending past the cumulative PV for May divided by the incremental amount of PV planned for June determines the fraction of the June schedule that has been earned.

Evolution of Earned Schedule

The ES concept was conceived during the summer of 2002 and was publicly introduced in March 2003 with *The Measurable News* article, *Schedule Is Different* [2]. This was quickly followed a few months later by the complementary article, *Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data* [3]. Using EVM data from several completed real projects, this second article verified the ES measure and its derivative indicators functioned as described in the seminal article *Schedule Is Different*. From that time, the behavior of the calculated measure of ES and its indicators has been verified many times by practitioners using real data from various types of projects.

Schedule Is Different alluded to the potential of using ES to forecast when a project would complete, but did not develop the equations. The second article [3] identified a schedule duration predictor analogous to the predictor for final cost, BAC/CPI. This schedule predictor, PD/SPI(t), where PD is the planned duration, was applied to real data and demonstrated the potential of the project duration and completion date prediction using ES.

Following the second article was *Further Developments in Earned Schedule* [4]. This article further expanded the ES schedule prediction and algebraically compared the ES methods with other published techniques. Two ES predictive calculation methods were identified as the *short form* and *long form*. The short form is as described previously, IEAC(t) = PD / SPI(t), where IEAC(t) is termed the Independent Estimate at Completion (time). The long form, just as for the short form, mimics an equation for forecasting final cost: IEAC = AC + (BAC - EV) / PF, where PF is a selected performance factor [1]. The long form schedule duration equation is as follows: IEAC(t) = AT + (PD - ES)/ PF(t), where AT is the actual duration, and PF(t) is a selected time performance factor.

In the *Further Developments in Earned Schedule* article, two common methods of schedule prediction were used for comparison to the predictive performance of ES [5]. The first method uses SPI from EVM, and the second applies a performance factor termed the *critical ratio*. The critical ratio is equal to SPI multiplied by CPI. The short form results were compared against two scenarios, early finish and late finish performance. Using data from two real projects discussed in the article, the results for the three forecasting methods are tabulated in Table 1 (see page 28) [4]. Only the ES forecast yielded correct results for both early and late completion. Neither of the other two methods provided correct results in either scenario.

In the same article, the long form equation was shown to provide correct end point results, regardless of the PF(t) used [4]. Thus, the long form equation possesses the identical characteristic of its companion equation for forecasting final cost. This characteristic of calculating and obtaining the correct result at project completion is required for the exploration and research of potential schedule based performance factors.

As the application of ES grew, it was recognized that there needed to be a common set of terminology. The interested parties involved agreed to a common theme: The terms should be parallel to, but readily distinguishable from those of EVM. It was thought that these characteristics would encourage the application of ES by minimizing the learning curve required. As seen from Table 2, ES Terminology, the chosen terms are comparable to those from EVM. In most instances, the ES term is simply the analogous EVM term appended by the suffix (t).

After the ES method was published in March 2003, it rapidly became viewed as a viable extension to EVM practice. By fall of 2003, the Project Management Institute - College of Performance Management (PMI-CPM) had become interested in the new practice. Within the next year an *emerging practice* insert citing the principles of ES was included in the 2004 release of the PMI-CPM *Practice Standard for EVM* [1].

With increasing use and interest in ES came the question, *does ES provide the long sought bridge between EVM and the network schedule?* Mainstream EVM thought is that other than the creation of the PMB, there can never be a strong connection between these two management components. The reasoning is EVM provides a macro-type assessment of performance but cannot yield the detail required to assess the true schedule performance.

Two articles, one published June 2005 and the other spring 2005, addressed the question of how ES contributes to making the direct connection between the schedule and the EVM data. The June 2005 article is appropriately titled *Connecting Earned Value to the Schedule*, while the spring 2005 article is *Earned Schedule in Action* [6, 7]. The *Connecting Earned Value* article describes how ES facilitates the bridge. The value of ES coincides with a PV point on the PMB. In turn, the PV is directly connected to specific tasks or work packages either completed or in work. Having this identification allows determination of how well the schedule is being followed. Differences in plan versus the actual distribution of EV provide insight as to which tasks may have impediments constraining progress and which have the possibility of future rework. The article introduces a measure of schedule adherence, directly connecting EVM to the network schedule, termed the *P-Factor* [6]. This new measure has lead to a theory which may prove to yield earlier and better prediction for both cost and schedule.

A considerable amount of interest has been shown for *Earned Schedule in Action*. The article compares the results from applying ES and Critical Path (CP) duration prediction methods to a small scale yet time-critical IT project. What was observed during project execution is the duration predicted from ES converged to the actual, final value from the pessimistic side, while the forecast from CP analysis converged optimistically. Because the ES predictive method takes into account past schedule performance while the CP method may not, it has been conjectured that, in general, ES yields a more consistently reliable schedule forecast. Further research is needed to confirm this hypothesis.

One advantage of ES became obvious in the CP study. Prediction obtained from ES calculations is considerably less effort than the CP approach, which requires very detailed task-level bottom-up analysis of the network schedule.

As a final point, the two articles discussed here provide rationale for the position that ES *bridges* the two disciplines of EVM and network schedule analysis. Even so, just as for cost, neither EVM nor ES can completely supplant bottom-up estimation techniques. For both, their respective predictive calculations are useful as macro methods for rapidly generating estimates and as a cross check of the corresponding bottom-up analysis.

Applications

Early in the existence of ES, some construed that the methods are limited in application. They believed that ES could only be used successfully for small information technology (IT) type projects. This perception occurred because software and IT projects were the environments in which the concept was created and first applied. The presumption is demonstrably false. ES is scalable up or down, just as is EVM. As well, ES is applicable to all types of projects, as is EVM. It follows that the scalability and applicability characteristics must exist; *after all, ES is derived from EVM.*

ES is known to be used in several organizations and countries for a variety of project types. Small IT and construction projects as well as large defense and commercial endeavors have employed and continue to include ES as part of their management toolset. The users have reported an increased ability to forecast future outcomes and the capability to identify late occurring problems that are masked when viewing EVM data alone. Significant applications in the

Table 1: *IEAC(t) Comparison*

	Early Finish Weeks	Late Finish Weeks
Planned Duration	25	20
Actual Duration	22	34
CPI	2.08	0.52
SPI	1.17	1.00
SPI(t)	1.14	0.59
PD/SPI(t)	22.0	34.0
PD/SPI	21.4	20.0
PD/(CPI * SPI)	10.3	38.7

United States are at Lockheed Martin, Boeing Dreamliner, and the Air Force (use in acquisition oversight). The United Kingdom Ministry of Defence has identified two major programs applying ES: Nimrod (maritime patrol aircraft) and Type 45 (Naval destroyer). Several smaller applications, mostly IT-related projects, have occurred in Belgium by Fabricom Airport Systems, as well as in the United States and Australia.

Research

Small-scale research has occurred throughout the evolution of ES. Each idea and next step has been applied and examined against real project data. However, due to data limitations, the testing and conclusions are not considered sufficiently complete. Although lack of testing is a drawback, the risk associated with ES usage is minimal. One compelling point supporting ES is that, regardless of the circumstances of the application (who, project type, company, country), the findings from all sources are consistent. The ES method, in every application, outperforms other EVM-based methods for representing schedule performance.

A research team at the University of Ghent, Belgium has recently published findings comparing ES to other project duration methods based on EVM measures [8]. Their conclusions coincide with the statement above; ES is the better performer. This research team has aspirations to perform rigorous testing of ES and the other prediction methods, using simulation techniques. They have also indicated interest in exploring the implications of the P-Factor (the measure of schedule adherence) discussed earlier.

	EVM	Earned Schedule
Status	Earned Value (EV)	Earned Schedule (ES)
	Actual Costs (AC)	Actual Time(AT)
	SV	SV(t)
	SPI	SPI(t)
Future Work	Budgeted Cost for Work Remaining (BCWR)	Planned Duration for Work Remaining (PDWR)
	Estimate to Complete (ETC)	Estimate to Complete (time) ETC(t)
Prediction	Variance at Completion (VAC)	Variance at Completion (time) VAC(t)
	Estimate at Completion (EAC) (supplier)	Estimate at Completion (time) EAC(t) (supplier)
	Independent EAC (EAC) (customer)	Independent EAC (time) IEAC(t) (customer)
	To Complete Performance Index (TCPI)	To Complete Schedule Performance Index (TSPI)

Table 2: *ES Terminology*

What's Next?

The expectation is the application of ES will continue to expand and propagate, coincident with the worldwide expansion of EVM. As ES is used more and more, it is reasonable to believe there will be increasing demand for its inclusion in EVM tools. Our conjecture is that the availability of tools employing ES is forthcoming in the near future. Along with increased application and tool availability, ES training will be requested as part of the provided EVM course. And most certainly as the use of ES expands, more information will be published, which will improve and mature the method and add to a rapidly expanding *ES Body of Knowledge*. Ultimately, we foresee that ES will become generally accepted and subsequently included within Earned Value Management standards and guidance. Finally, it is our belief that ES will lead to improved prediction techniques for both cost and schedule.

Available Resources

There is a considerable amount of accessible ES information to aid current and potential users. Published papers, conference presentations, and workshop materials are available from two Web sites: <www.earnedschedule.com> and <http://sydney.pmichapters-australia.org.au/> (Education, then Papers and Presentations). Both sites offer downloading of the information free of charge. Additionally, calculators facilitating the application of ES are available from <www.earnedschedule.com>.

Summary

ES was created as a non-complex solution to resolve the problem of the EVM schedule indicators failing for late-finishing projects. The ES method requires only the data available from EVM and has been shown to provide better prediction than other EVM-based methods. Duration forecasting using ES is easier to do than detailed, bottoms-up estimation, and possibly yields better results, as well. ES is scalable up or down, and it is applicable to any project using EVM. ES facilitates identification of tasks with possible impediments, constraints, or future rework and has the potential to improve both cost and schedule prediction.

ES is a powerful new dimension to integrated project performance management and practice. It has truly become a breakthrough in theory and application.◆

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About the Authors

Walt Lipke recently retired as the deputy chief of the Software Division at the Oklahoma City Air Logistics Center. He has more than 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 first Air Force activity to achieve Level 2 of the Software Engineering Institute's Capability Maturity Model (CMM) in 1993; the first software activity in federal service to achieve CMM Level 4 distinction in 1996; division achieved ISO 9001/TickIT registration in 1998; and the division received the SEI/IEEE Award for Software Process Achievement in 1999. He is the creator of Earned Schedule©, which extracts schedule information from earned value data. Lipke is a graduate of the U.S. Department of Defense course for Program Managers. He is a professional engineer with a master's degree in physics.

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Web Sites

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We must reject the idea that the primary path to greatness in the social sectors is to become more like a business. Most businesses fall somewhere between mediocre and good. Few are great. When you compare great companies with good ones, many widely practiced business norms turn out to correlate with mediocrity, not greatness. So, then, why would we want to import the practices of mediocrity into the social sectors?

Agile Alliance

www.agilealliance.org

The Agile Alliance (AA) is a non-profit organization that supports individuals and organizations who use Agile approaches to develop software. Driven by the simple priorities articulated in the Manifesto for Agile Software Development, Agile development approaches deliver value to organizations and end users faster and with higher quality. The AA exists to help more Agile projects succeed and to help the enthusiasts start more Agile projects. The AA is uncovering better ways of developing software by doing it and helping others do it, and have come to value individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, and responding to change over following a plan.