Earned Schedule - the First 20 Years

Introduction

The concept of Earned Schedule (ES) was introduced to the Earned Value Management (EVM) community in March 2003, when Walt Lipke published *Schedule is Different*[1] in the College of Performance Management (CPM) *Measurable News*.

Earned Schedule[2] is an extension to the EVM system that provides an enhanced ability to predict project completion dates, and is the bridge for performing meaningful schedule analysis from EVM data. It uses the same data as traditional EVM, but shifts the calculations from the cost axis to the time axis.

Despite early controversies over the approach, studies by a range of universities and other authorities have shown the project duration predictions calculated by ES are as accurate as the cost predictions generated by traditional EVM. Twenty years after its creation, ES is now seen as a standard component of EVM and is included in most published Standards including ISO and ANSI/PMI.

Definitions

Before tracing the development of Earned Schedule and its contribution to the discipline of project management, it is important to precisely define what is meant by Earned Schedule and Earned Value Management in the context of this paper.

Earned Schedule (ES)

As outlined above, Earned Schedule is an extension of Earned Value Management, it is defined in ISO 21508:2018 *Earned value management in project and programme management*, and ANSI/PMI 19-006-2019 *The Standard for Earned Value Management.*

The primary function of ES is to predict the project completion date based on the value of work planned to be completed (PV) and actual value of work accomplished (EV) in a particular period, or as at a nominated date, using data contained in the project's EVM system. It extends the capabilities of traditional EVM by calculating schedule metrics and indicators on the time axis, including SPI(t) and SV(t) as well as the predicted project completion date. Consequently, the prerequisites needed to implement ES are a project, running an EVM system (EVMS) as part of the overall project controls framework.

Note: ES is derived from and forms part of an EVMS. It has no connection to any other time management and/or time payment, and/or incentive payment system, as used in various factories, mills and projects. These time management/payment systems have a long history and many are still in use today, but it is important to note that ES is not a time recording, time management or payment system.

1 Lipke, Walt. ***Schedule is Different***. The Measurable News, March & Summer 2003. Download from: https://mosaicprojects.com.au/PDF-Gen/Schedule_is_different.pdf

2 For more on Earned Schedule and access to the ES templates see: https://www.earnedschedule.com/

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Earned Value Management (EVM)

The concepts of Earned Value Management, and an Earned Value Management System (EVMS) used in this paper are based on the two standards detailed above, plus NDIA/EIA 748-D, *Earned Value Management Systems (EVMS)*. While the management focus, acronyms, and some details vary between these three standards, they are consistent in their approach to defining what EVM is, and what it is not.

The standards define EVM as a project performance management system[3]. The basic requirement needed to establish an EVMS is an identified project, in which the responsibilities of each manager is defined by reference to a Work Breakdown Structure (WBS)[4]. Then the EVMS creates *measures of performance* at the Work Package and Control Account levels and rolls this information up to the overall project level.

The core drivers of an EVMS are the value of work planned to be accomplished (PV), the value of the work actually completed (EV), and the actual costs incurred in accomplishing that work (AC); either in a reporting period, or cumulative to the date of the assessment. The value metric most commonly used in an EVMS is money, but any measure of value that is uniform across the project can be used (eg, work hours).

An EVMS as defined in the standards is not a cost engineering system, a financial controls system, or a payment/contract management system. These other systems form an important part of a well-managed project's overall controls system, but their connections to the EVMS are limited.

Traditional EVM

EVM Origins

EVM developed from PERT/COST and cost engineering in the 1970s. In the 1960s, the US Government had identified difficulties in measuring cost performance and predicting likely cost outcomes, based on the existing cost engineering[5] and financial control systems used for major defense acquisition projects. This challenge was particularly acute on major cost-plus development contracts for new missiles, aircraft, etc.

Senior management in the US Dept. Defense perceived the time-focused controls information produced by the recently introduced PERT and CPM scheduling systems[6] to be a significant improvement over the management information previously available, and wanted a similar capability in respect to project costs. The first system implemented to achieve this objective was PERT/COST, which was superseded by the introduction of EVM in the early 1970s[7].

The major changes in focus between cost engineering and EVM were:

1. EVM data is compiled at the management control point, whereas cost engineering data is focused on the individual cost items (line items)

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[3] See ***The Purpose of Earned Value Management***: https://mosaicprojects.com.au/Mag_Articles/AA025_The_Purpose_of_Earned_Value_Management.pdf

[4] The concept of a formal WBS structure emerges as part of the PERT, and PERT/COST, developments in the late 1950s and 60s. For more on the ***history of WBS*** see: https://mosaicprojects.com.au/PMKI-ZSY-020.php#WBS

[5] For more on the ***history of cost engineering*** see: https://mosaicprojects.com.au/PMKI-ZSY-020.php#Process1

[6] The project scheduling systems developed in 1957 and in general use by the early 1960s were:
- **PERT**, Project Evaluation and Review Technique, see ***Origins and limitations of PERT***: https://mosaicprojects.com.au/PMKI-ZSY-030.php#Process2
- **CPM**, Critical Path Method, see ***Origins of CPM***: https://mosaicprojects.com.au/PMKI-ZSY-030.php#Overview

[7] For more on the ***history of PERT/COST and EVM*** see: https://mosaicprojects.com.au/PMKI-ZSY-020.php#EVM

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2. EVM is a proactive management system; both cost engineering and EVM identify cost variances, but the EVM system places a positive obligation on the responsible manage to identify the cause of the variance and what actions will be taken to mitigate or eliminate negative variance
3. The EVMS has formal processes for predicting the project's likely cost outcome based on the use of a predefined standard formula.

Cost engineering does not preclude managers using the variance and cost to date data to manage the consequences of a cost variance and to predict the likely cost outcome of the project[8]. The difference is cost engineering assumes a sensible manager will do these things in an appropriate way; EVM defines the reporting standards and calculations that will be used.

EVM Design Focus

As outlined above, the focus of EVM was on cost performance, PERT and CPM provided time management capabilities. As developed, the EVM system was designed to deliver focused management information at the work package and control account level that was then rolled up to the overall project:

- **Cost Variance** (CV) identifies the difference between the planned cost of the work accomplished (EV) and the actual costs (AC) incurred doing the work
- **Schedule Variance** (SV) identifies the difference between the amount of work planned to be accomplished (PV) and the amount of work actually achieved (EV)

Based on this information, management action is expected to remove negative variances!

The major enhancement in project controls introduced with PERT/COST and refined in EVM was the improvement in predicting the likely cost outcome for the project based on the project's performance to date. Unlike the PERT and CPM scheduling tools, which assume all future work would be performed in accord with the plan, EVM assumes the best indicator of future performance is the actual performance to date. The Cost Performance Index (CPI) is a ratio between the planned value of the work accomplished (EV) and its actual cost (AC), and this ratio is applied to future costs to determine the likely cost outcome. The standards define several ways of doing this calculation, the project chooses the one best suited to its needs and then applies the formula consistently.

The design intent of EVM was to improve the management of cost performance and it has achieved this objective. However, the predictive capability of EVM was limited to cost. The reason for this is quite simple, once the project is 100% complete, 100% of the planned work will have been done. Therefore, the planned value and the earned value will be equal, meaning SV = $0 and SPI = 1.

Despite this design feature, SV and SPI are reliable indicators during the early portion of the project that show if adequate quantities of work are being accomplished to maintain the plan. This information augments the information available from a CPM update:

- The CPM update will tell management if the work on the critical path is being achieved as planned, and the expected completion date based on the recalculated schedule

[8] An early example of predicting the final cost outcome on a major project can be found in the reports of the Royal Commissioners responsible for running the very successful Great Exhibition of 1851. In their second report, the Commissioners predicted a profit of not less than £178,000, a couple of years later their final prediction was for a profit of not less than £186,436 18s and 6d (in pounds, shilling and pence).
See: https://mosaicprojects.com.au/PDF_Papers/P180-Project_Governance-Building_the_Crystal_Palace.pdf

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- The SV data tells management if enough work is being accomplished overall to meet the program requirements.

The limitation of EVM is that if the SV data shows insufficient work is being done, there is no way of converting a SV of (say) -$25,000 into a period of time. The reason for this is the way the data set is constructed, all of the data points used relate to cost:

- The basis of the cost calculations is:
  - The budget at completion (BAC) is a fixed value
  - The value of work accomplished (EV), is a part of the BAC, when all of the work is finished 100% of the BAC has been earned therefore the EV has a finite range of 0% BAC (nothing done) to 100% BAC (everything finished)
  - However, the actual costs of performing the work are unlimited, one hopes the actual costs will be close to the budgeted costs, but achieving this depends on management skill. The Independent Estimate at Completion (iEAC) is not constrained by the planned values
- The basis of time calculations is:
  - The value of work planned to be accomplished (PV). This is based on the BAC, when all of the work is finished 100% of the BAC will have been completed, therefore the PV has a finite range of 0% BAC (nothing done) to 100% BAC (everything finished)
  - The value of work actually accomplished (EV), is also a part of the BAC. When all of the work is finished 100% of the BAC has been earned therefore the EV has a finite range of 0% BAC (nothing done) to 100% BAC (everything finished)
  - Both of these values are constrained by the planned budget at completion, neither relate to time. While there is a planned overall duration for the project's work, the actual time needed to complete the project is unconstrained, but this factor cannot be measured or calculated using only PV and EV.

The value of EVM

The value of EVM was, and is, the creation of a predictive project controls tool that provides concise current performance metrics identifying the quantity of work accomplished compared to the plan and the actual costs paid to accomplish the work compared to its planned value. This information allows management action to be focused where it is needed[9].

EVM also provides a reliable indicator of the likely cost at completion of the project based on performance to date. This prediction has been found to be more accurate than other approaches used to estimate the project's final cost, but does assume future work will be performed in a similar way to the work already done. If you change the way work is done, you are likely to change the predicted outcome.

[9] For more on ***practical ways to manage a project using EVM*** see: https://mosaicprojects.com.au/PMKI-SCH-040.php#Process1

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Predicting the Project Completion Date

Predicting completion before ES

The need to predict the likely completion date of a project has always been important, with the introduction of CPM in the 1960s, and EVM in the 1970s there appears to have been two basic options for making this prediction:

- Look at the updated schedule
- Look at the EVM data from a time perspective.

Updating the schedule.

A properly updated dynamic CPM schedule moves all incomplete work to the right of the data date (Time Now), adjusts the schedule to remove anomalies, and reschedules the incomplete work from the data date to establish a new project completion date and identify the current critical path(s) through to completion[10]. The CPM analysis may be either a time analysis, or a resource analysis, depending on the needs of the project and what has been used previously.

The structural limitation inherent in CPM is an assumption that all future work will occur as planned. There is no accepted methodology for adjusting future work durations or resource requirements based on performance to date. This assumption that all future work will go as planned tends to make the results from a CPM update process a very optimistic assessment of the likely project completion[11].

Reframing EVM data – the UK approach.

A range of approaches to reframing and using EVM data to provide an estimate of the likely project completion date appear to have been used by EVM practitioners over the years. The best documented of these approaches is included in BS 6079-1:2000[12].

Clause ***4.6.6.5 Forecasting based on earned value statistics*** calculates the forecast completion date and the time needed to complete the project as follows:

Where:

ATE = Actual Time Expended for the work to date

EATC = Estimated Actual Time to Complete

ETPT = Estimated Total Project Time

OD = Original Duration planned for the work to date

PTC = Planned Time to Complete

PTPT = Planned Total Project Time.

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10 For more on ***updating and maintaining a CPM schedule*** see: https://mosaicprojects.com.au/PMKI-SCH-014.php#Process6

11 For more the innate optimism built in to CPM see ***Why Critical Path Scheduling is Wildly Optimistic!***: https://mosaicprojects.com.au/PDF_Papers/P117_Why_Critical_Path_Scheduling_is_Wildly_Optimistic.pdf

12 British Standard 6079-1:2000 Project Management – Part 1: Guide to Project Management. Incorporating Amendment Nos. 1 and 2 to BS 6079:1996.

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Time based SPI = $\frac{\textbf{OD}}{\textbf{ATE}}$

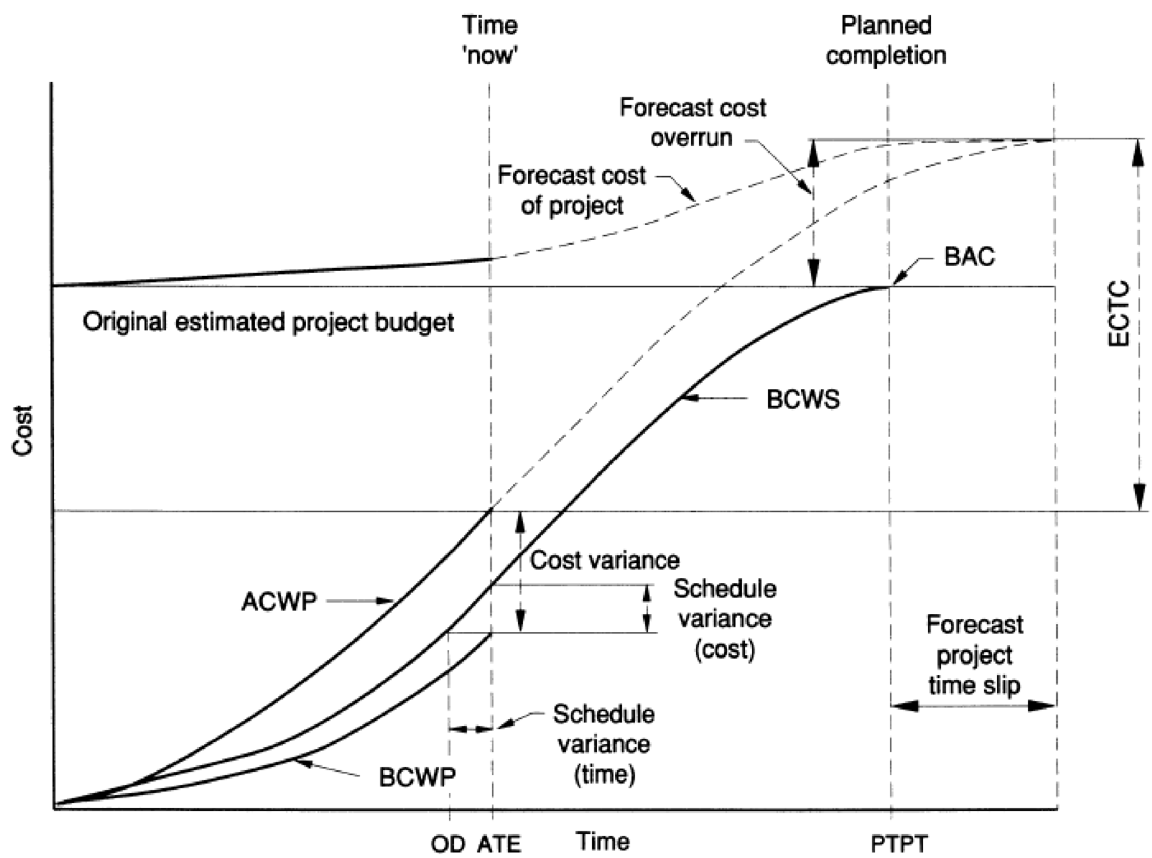
Planned Time to Complete (PTC) = **PTPT - OD**

Estimated Actual Time to Complete (EATC) = $\frac{\textbf{PTC}}{\textbf{SPI (time)}}$

Estimated Total Project Time (ETPT) = **ATE + EATC**

Forecast Project Time Slip = **ETPT - PTPT**

The relationship between these calculations can be seen in the diagram below.



© BS 6079-1:2000 Project Management – Part 1 Guide to Project Management, Figure 8

The limitations in this approach are the lack of defined ways to assess time, ATE is a known date (Time Now), but the assessment of OD date is a visual process. Once the OD date has been assessed, the project calendar will allow the conversion of dates into working days for the calculations to be performed. But different people can use different calendar information, working days, calendar days, weeks, or months.

The concept of OD, ATE, *Schedule variance (time)*, and the *Forecast project time slip*, can be seen in most current British, and UK standards. However, the calculations outlined above have been dropped from the publications, probably due to the lack of a standard approach to defining time units. In 2010, the UK based Association for Project Management (APM) published *Earned Schedule - An emerging Earned Value technique*, validating the use of ES as an extension to the APM EVM Guide.

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Reframing EVM data – the USA approach.

A number of EVM practitioners based in the USA have also stated they used various means to assess project completion based on the EVM data[13]. As outlined in ***The Origins and History of Earned Value Management***[14], the cooperation between the UK and USA in developing and promoting EVM was significant so it is highly probable that variations of the British Standard approach outlined above was used in part of the USA, and USA practices may have fed into the development of the British Standard.

However, the official approach to predicting the project completion date (mirrored in Australia) was defined in *ANSI/EIA-748-1998 Earned Value Management Systems*. ***Clause 3.8.1 Schedule Performance*** states in part:

> *Program schedules will involve time-oriented listings or graphic representations of the work to be done on the program. The schedule activities and events are monitored for management information. Each process provides useful and valuable information that aids in comprehending program conditions. The schedule variance metric provides early insight into detail schedule conditions and overall schedule performance and should be used in conjunction with milestone status reports, critical path data, and other schedule status information used by the company. The schedule variance metric considers both ahead-of-schedule and behind-schedule data in the computation of an overall schedule position.* ***Other techniques, such as critical path analysis, are preferred indicators of long range projections; but, a trend analysis of the changes in the schedule variance metric can provide a valid and useful indication of current performance and near-term projections****.* [emphasis added]

The same paragraph occurs in *EIA-748-A 2002* and would appear to represent the view of the USA defense/industry EVM community at that time[15].

ES Enhancements to EVM

The primary innovation introduced by ES is reframing the EV cost data to the time dimension without the need to introduce additional data sets such as the project calendar[16]. It uses the same time periods as the standard EVM reports (usually monthly) and the standard EVM PV and EV cost data. The ES calculations (normally run in a free ES Excel spreadsheet[17]) are precise, predictable and repeatable and can be directly traced back to the rest of the EVM reporting structure.

The data points used are the cumulative earned value (EV) at Time Now (or the data date), the number of reporting periods from the start of the project to Time Now, and the number of reporting periods from the project start through to the point where the cumulative planned value (PV) equals the cumulative EV.

13 One example from the 2008 is detailed in: Smith, K. F. (2023). *On the subject of project schedule and completion forecasting*, Letter to the Editor, PM World Journal, Vol. XII, Issue IV, April. Available online at https://pmworldjournal.com/wp-content/uploads/2023/04/pmwj128-Apr2023-Smith-on-project-schedule-forecasting-Letter-to-Editor.pdf

14 Download ***The Origins and History of Earned Value Management*** from: https://mosaicprojects.com.au/PDF_Papers/P207_EVM_History.pdf

15 Download the original EIA-748 from: https://mosaicprojects.com.au/PMKI-ZSY-020.php#EVM-Ref

16 A full listing of the innovations introduced to EVM by ES can be found at: https://www.earnedschedule.com/Docs/ES%20Enhancements%20to%20EVM.pdf

17 **Note**: A number of EVM software tools also include ES as part of their capabilities.

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This shift to the time axis removes the constraint affecting traditional SV calculations, the number of time periods to Time Now is unconstrained in the same way actual costs (AC) are unconstrained in traditional EVM, meaning the time-based calculations and ratios will function in the same way as the traditional cost-based calculations and ratios. The method of calculation also eliminates the visual assessments inherent in the British Standard approach outlined above.

Predicting completion using ES

This paper will not provide a detailed tutorial on implementing ES[18], beyond offering a quick overview of the standard calculations built into the ES system.

The basic structure of ES

The two tables below, copied from the Earned Schedule website, identify the common terminology used for Earned Schedule (ES). The first table indicates the accepted EVM terminology for cost and then displays, comparatively, the ES terminology for an analogous measure or indicator.

	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 (IEAC) (customer)	Independent EAC (time) IEAC(t) (customer)
	To Complete Performance Index (TCPI)	To Complete Schedule Performance Index (TSPI)

The second table breaks down the ES terminology to measures, indicators, and predictors. The terminology depicted in this table has a few terms requiring definition:

PD = Planned Duration

ED = Estimated Duration

PF(t) = Performance Factor (time-based)

The time-based performance factor is analogous to the PF used in the EVM IEAC equation.

[18] To access ***information on implementing ES*** in a project see: https://www.earnedschedule.com/

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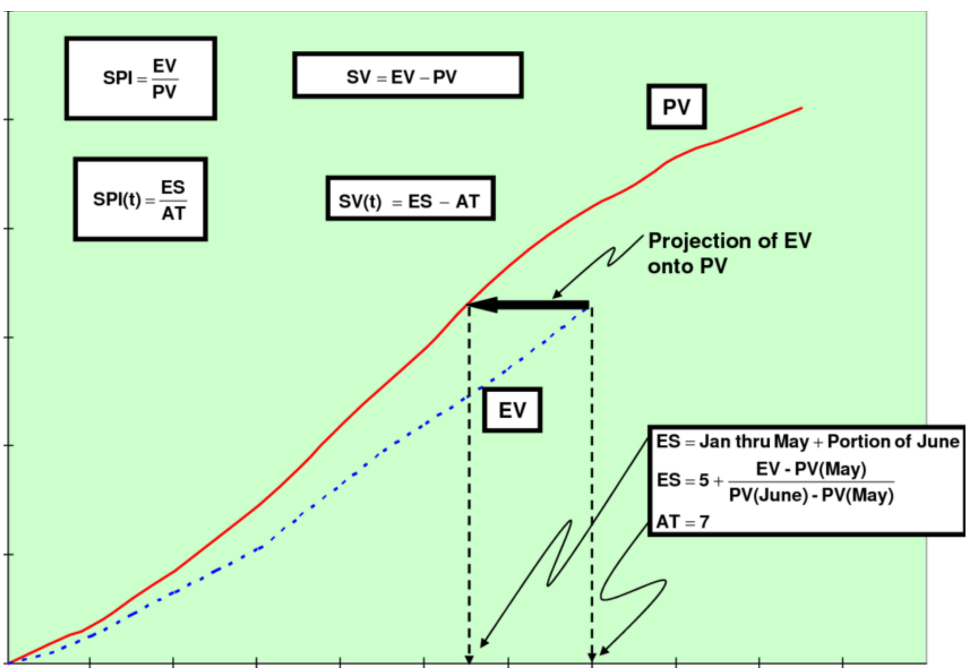
Metrics	Earned Schedule	ES_{cum}	ES = C + I number of complete periods (C) plus an incomplete portion (I)
	Actual Time	AT_{cum}	AT = number of periods executed
Indicators	Schedule Variance	SV(t)	SV(t) = ES – AT
		SV(t)%	SV(t)% = (ES – AT) / ES
	Schedule Performance Index	SPI(t)	SPI(t) = ES / AT
	To Complete Schedule Performance Index	TSPI	TSPI = (PD – ES) / (PD – AT)
			TSPI = (PD – ES) / (ED – AT)
Predictors	Independent Estimate at Completion (time)	IEAC(t)	IEAC(t) = PD / SPI(t)
			IEAC(t) = AT + (PD – ES) / PF(t)
	Variance at Completion	VAC(t)	VAC(t) = PD - IEAC(t) or ED

Calculating ES

The calculation of AT and ES are based on reporting periods, this is usually a monthly cycle, but the system can accommodate any sensible reporting period.

The calculation at the core of ES is determining the number of reporting periods from the project start, through to the point where $PV_{cum} = EV_{cum}$.



In the example above:

PV_{cum} End May = $123,000

PV_{cum} End June = $134,000

EV_{cum} End July = $128,000

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To calculate the time at which PV = EV, we need the five full months from the project start at the beginning of January to the end of May ($123,000), plus a portion of PV in June, therefore:

$$\mathbf{ES} = 5 + \frac{(128{,}000 - 123{,}000)}{(134{,}000 - 123{,}000)} \text{ which } = 5 + 0.4545 \text{ or } \mathbf{5.4545} \text{ months.}$$

This calculation is based on the premise that the rate of accumulation of PV is constant through the month.

Other ES features

The transition from predicting cost outcomes to predicting time outcomes is not straightforward. For example, the project may stop work for a period due to an excusable delay, which is compensated by an authorized extension of time (EOT), there is a 1:1 relationship between the delay and the EOT which does not affect the performance of work at other times.

In addition to the basic features discussed in this paper, the Earned Schedule tool has the capability to:

- Forecast accurately when project has interruptions
- Offer improved forecasting using *Longest Path* for projects having highly parallel path schedules
- Perform statistical forecasting
- From schedule adherence analysis (discussed below):
    - determine tasks which may have impediments or constraints, to compute cost and duration impact, and
    - trend the schedule adherence index
- Create the To Complete Schedule Performance Index (TCSPI), and compute the probability of achieving a successful project recovery based on the research establishing the 1.10 threshold.

The Earned Schedule analysis method can be applied to subsets of the overall project simply by segregating and grouping EVM data for a specific portion of the project and setting up a separate ES template for that portion of the work. For example, by selecting and analyzing the schedule performance of work packages (or activities) on the critical path or assigned to an identified subcontractor[19].

Does ES work?

Given the ES system briefly outlined above is documented, definable and repeatable, the key question is: does the ES calculations provide an accurate prediction of the likely project completion date?

The calculations are straightforward, and are directly comparable to the cost calculations in EVM. For example, in the example used above, the overall planned project duration is 9.6 months, therefore based on the ES data as at the end of July,

$$\text{SPI(t)} = \frac{5.4545}{7} = 0.779\text{, therefore}$$

$$\text{IEAC(t)} = \frac{9.6}{0.779} = 12.32 \text{ months (meaning the project completes around the } 10^{th} \text{ January)}$$

But does this work in the real world?

[19] See: https://earnedschedule.com/Docs/Applying%20ES%20to%20Critical%20Path%20and%20More.pdf

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The research

Over the last 20 years a significant body of research has been accumulated that demonstrates the ES time calculations are as reliable as the cost calculations in traditional EVM, as demonstrated in this brief selection of key papers:

1. ***Earned Schedule: A Breakthrough Extension to Earned Value Theory?, A Retrospective Analysis of Real Project Data***[20] Kym Henderson (Summer 2003). Six IT projects evaluated.
   Conclusions:
   The retrospective analysis of ES using my own EVM project data, whilst anecdotal due to the small sample size, has confirmed with remarkable precision the accuracy of the ES concept and ES metrics SV(t) and SPI(t)……. The ES metrics are expected to behave consistently with their EVM cost based counterparts because they have correctly correlated the project's actual schedule performance across all phases of the project for both late and early finish example projects.

2. ***A comparison of different project duration forecasting methods using earned value metric***[21] Stephen Vandevoorde, Mario Vanhoucke (May 2006). Three airport construction projects evaluated.
   Conclusions:
   The earned schedule method seems to provide valid and reliable results along the project's lifespan.

3. ***A simulation and evaluation of earned value metrics to forecast the project duration***[22]***.*** Mario Vanhoucke, Stephen Vandevoorde, (October 2007). The researchers generated 3100 project schedules and nine different simulations to test PV, ES, and ED.
   Conclusions:
   The results reveal that the ES method outperforms, on average, all other forecasting methods.

4. ***A Comparison of Earned Value Management and Earned Schedule as Schedule Predictors on DoD ACAT I Programs***[23] Kevin T. Crumrine, Captain, USAF (March 2013). 64 programs studied.
   Conclusions:
   Our series of tests confirmed that Earned Schedule is a more accurate schedule predictor than the Earned Value Management technique currently employed by the Department of Defense on Major Defense Acquisition Programs.
   The SV($) metric is comparatively useless over the final half of the program, while Earned Schedule provides meaningful information over the entire life of a program.

5. ***Testing Earned Schedule Forecasting Reliability***[24]***.*** Walt Lipke, (July 2014). A review of previous studies and their findings.

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[20] The Measurable News, Summer 2003. Download from: https://www.earnedschedule.com/Docs/Earned%20Schedule%20-%20A%20Breakthrough%20Extension%20to%20EVM.pdf

[21] International Journal of Project Management. 24. 289-302. https://www.sciencedirect.com/science/article/abs/pii/S0263786305001080

[22] The Journal of the Operational Research Society, Vol. 58, No. 10 (Oct., 2007), pp. 1361 - 1374. https://www.jstor.org/stable/4622825

[23] Thesis, Presented to the Faculty, Department of Systems Engineering and Management, Graduate School of Engineering and Management, Air Force Institute of Technology. Download from: https://scholar.afit.edu/cgi/viewcontent.cgi?article=1987&context=etd

[24] PM World Journal, Vol. III, Issue VII (July 2014). https://pmworldlibrary.net/wp-content/uploads/2014/07/pmwj24-jul2014-Lipke-testing-earned-schedule-forecasting-reliability-FeaturedPaper2.pdf

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Conclusions:
it is reasonable from the results of this study to conclude that project managers employing EVM can have confidence in the forecasts made using ES.

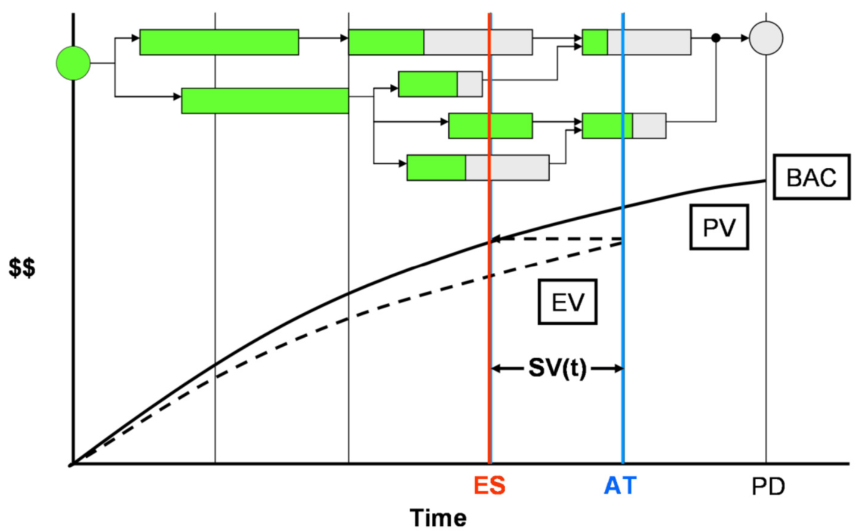
The Standards

ES is now an integral part of the following standards:

1. ISO 21508, *Earned value management in project and programme management*
2. ISO 21512, *Project, programme and portfolio management – Earned value management implementation guidance* (publication due 2023)
3. ANSI/PMI 19-006-2019 *The Standard for Earned Value Management*
4. NDIA-IPMD companion guides to EIA 748:
    a. ***Predictive Measures Guide*** – 2017
    b. ***Planning and Scheduling Excellence Guide*** (PASEG)
5. AS 4817:2019 *Earned value management in project and programme management (ISO 21508:2018, MOD)*

Schedule adherence

In 2004, less than a year after ES was developed, the impact of rework caused by activities being performed out of sequence became apparent. The concept of Schedule Adherence (SA), derived from ES analysis, provides methods for assessing the impact of performing project tasks out of their planned sequence. Schedule Adherence, expressed as the P-Factor can be used to adjust the measured EV to the effective earned value.



Applying SA analysis accounts for the effect of rework by applying amended formulas for schedule performance indicators and forecast within the ES model. Formulas are provided for computing the amount of change rework causes to schedule performance. The computed value is a simple way for assessing the magnitude of the negative impact that rework may cause. It is noted that as the project progresses the potential for rework diminishes as the P-Factor converges to its final value, 1.00.

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The P-Factor is important! Time is not money, you can spend a reserve of cash at any time and its value does not change, but you only get to work on a day once, then it is history. This crucial difference makes the inclusion of the P-Factor in ES important. By including the P-Factor the consequences of work being performed out of sequence is managed. One criticism of volume-based controls system is that people will focus on the easy work in preference to the important work to boost EV in the short term, the P-Factor says 'OK', but only if the work is being done in the correct sequence.

Other predictive tools

In ***The Evolution of Project Management***[25], three phases of project control tools are identified:

1. **Static tools**. For most of history, the project controls process involved creating a plan, then measuring actual performance and comparing it to the plan to identify any variance. Then applying the innate skills of the manager to resolve undesirable variances. The plans (cost, schedule, other) were only changed occasionally, the effort needed to redraft documents created using pen and ink was significant and was rarely seen as a useful process. Many project and management systems still use static tools; they are simple and robust.
2. **Dynamic tools**. The increasing availability of computers from the 1950s on allowed the development of dynamic tools. The dynamic tools were designed to update the plan with current performance information and then recalculate the remaining portion of the plan from the current update. In addition to the current variance information the future consequences could be seen, assuming the rest of the project work was done as planned. Comparing the updated future with the project baseline provided management with a richer source of information and the ability to focus effort on the most important areas of the project needing improvement. Dynamic tools include critical path scheduling software and various financial, risk, and resource management systems. These form most of software systems in a project controls suite.
3. **Predictive tools**. The third stage of development was based on using the information gathered for the dynamic control tools to automatically adjust the duration, cost, and resources planned to be used for future activities, based on the performance to date and an appropriate algorithm. The basic assumption in a predictive system is that the best indication of future performance is the actual performance to date. This approach to project controls started in the 1960s and is continuing with the increasing use of artificial intelligence (AI) to facilitate the predictions. The first of the tools to apply this concept was Earned Value Management for the calculation of the Estimate At Completion (EAC).

Traditional EVM proved to be a reliable predictor of the cost at completion, with the accuracy of the prediction improving as work on the project progressed. The next generally available system was Earned Schedule, and its ability to predict the likely project completion date. As far as I am aware, the only other predictive time-based tool available for general use is Earned Duration.

Earned Duration (ED)

ED has similar capabilities to ES but needs more work to operate (assuming EVM is being used), the basis of the calculation is the Total Planned Duration, which results from assigning one time unit to each day of each activity and adding up all of those numbers for a certain working day (column) to reach the Total

[25] Download ***The Evolution of Project Management*** from: https://mosaicprojects.com.au/Mag_Articles/AA021_The_evolution_of_project_management.pdf

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Planned Duration (TPD) numbers (daily and cumulative) at the bottom of the schedule. By definition, each planned day of an activity has a weight of one, regardless of the effort, resources or costs involved in its execution.

The number of duration units earned is a simple calculation based on a schedule update, and the third element, the Actual Duration of an activity is the number of working days it actually took to complete the work. From these metrics, a similar set of calculations to EVM and ES can be used to predict the likely project completion date[26].

ES -v- ED

The assumption underpinning ES is the amount of effort needed to accomplish one $1000 worth of work will, on average be the same as any other $1,000 of work.

The explicit assumption in ED is the amount of effort required to accomplish one day's production on one activity will on average be the same as any other day's production on any other activity. This assumption is compounded by the challenge of assessing the ED for activities in progress, activities rarely start at the beginning of a day and most require a crew of people but a planned activity of 3 people for 10 days (30 days of effort) may actually start with one person, 2 on the next couple of days, then 1 part time, then 4 and still have a lot of work to do. The ED system has processes for dealing with this but they need to be applied individually to each in-progress activity and the information needed is not typically collected as part of a CPM update.

Both assumptions contain a degree of error but practical observation suggests 'swings and roundabouts' work for both ES and ED to produce a more realistic predicted completion date than that derived from a simple CPM update.

The oft-repeated assertion made by ED advocates that the value of work (money) is not a reliable indicator of the effort needed to accomplish the work, does not appear to be a valid critique. Statistically, ES is likely to be more reliable on average than ED because the number of dollars in a project are usually massively higher than the number of days in the TPD. But in reality, the choice between the systems will depend on what other control systems are in use:

- If the primary control tool is a CPM schedule ED is likely to be easier to implement
- If the primary control tool is EVM, ES is likely to be easier to implement[27]
- If both CPM and EVM are in use ES is likely to be easier to implement because the required data is already being gathered.

The primary reasons for this assessment is, that when using ES all of the determinations about how much of an in-progress work package has been completed (EV) is outsourced to the people doing the EVM update, using the predefined 'objective measures of progress'. ED requires the equivalent of this work to be done by the people running the ED system and appears to be more subjective.

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[26] **Note**: There appears to be a number of variations around the concept of ED published by different authors over a number of years. This brief outline is based on *Stochastic Earned Duration Analysis for Project Schedule Management*. Fernando Acebes, David Poza, José Manuel González-Varona, Adolfo López-Paredes. S. Published by Elsevier LTD on behalf of Chinese Academy of Engineering and Higher Education Press Limited Company. https://doi.org/10.1016/j.eng.2021.07.019 (2022)

[27] **Note**, many projects cannot make effective use of a CPM schedule requiring a quantity of work view of progress similar to ES. For more on project controls for this type of project see ***Schedule control in Agile and Distributed projects***: https://mosaicprojects.com.au/PMKI-SCH-010.php#Issues-A+D

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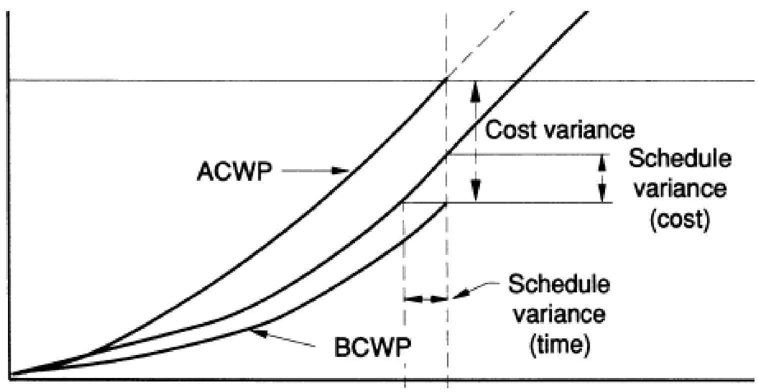
Conclusions

The research cited in this paper clearly demonstrates that overall ES is a reliable and practical tool for assessing the project completion date for projects using EVM. The ES analysis can be applied to the whole project or defined sections of a project to identify issues and opportunities. The advanced capabilities incorporated into ES provide more analysis capability than traditional EVM does for cost, or other schedule analysis methods can for time.

Unlike the CPM assumption that all future work will go as planned, ES is based on the premise that the best indicator for future performance is the past performance, particularly when a project is running behind schedule. EVM has demonstrated the validity of this approach for the last 60 years in respect to forecasting cost outcomes, ES builds on this legacy to predict time outcomes.

The art of management is based on interpreting information from a range of inputs to understand what has occurred and to make informed decisions to improve future outcomes. The value of ES is providing a richer data set for management to use that requires very little additional effort if the project has an effective EVMS in pace.



In a well-run project:

- SV (cost) is important at the work package level, a negative SV is likely to be the first indicator of an emerging problem:
    - CV usually follows SV
    - The CPM schedule may, or may not show a problem depending on float and where the critical path lies
- SV(time) at the project level shows how far behind plan, progress currently is based on the quantity of work (value) accomplished
- SPI(time) used in the ES formula will calculate the expected number of time periods needed to complete all of the project work, this information is easily converted to an approximate completion date[28] if nothing changes – the purpose of management is to make beneficial changes!
- An updated CPM schedule (or other planning process) completes the basic time controls process, the CPM update is needed to:
    - Organize the work going forward

[28] The assessment of the projected completion date is subject to minor discrepancies caused by the number of working days in a month, weekends, holidays, etc. This error is unlikely to be more than two days which is of little relevance for a projection several months (or years) into the future.

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- Set optimistic targets for people to work to achieve (these may also be contractual obligations)
- Provide a check on the ES predictions.

The reason CPM and ES are both needed is their focus. CPM updates will show if enough progress is being made on the critical activities in the project and the time consequences[29], SV will show if enough work overall is being accomplished, and ES will use the EVM data to predict the expected project completion date.

I am on the record as stating that every project running a proper EVM system (as defined by the standards), should also include ES in its controls suite. Setting up the ES system is a simple process done once, then all that is needed is to import the EVM progress data each month to generate new information and insights.

First Published 7th March 2023 – Augmented and Updated

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[29] **Note**, many types of project, including agile and distributed projects, cannot make effective use of a CPM schedule requiring a quantity of work view of progress similar to ES. For more on project controls for this type of project see ***Schedule control in Agile and Distributed projects***: https://mosaicprojects.com.au/PMKI-SCH-010.php#Issues-A+D

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