Earned Schedule in Action

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Abstract

Lipke's, seminal paper "Schedule is Different" [1] proposed the concept of "Earned Schedule" (ES) to provide time based measures of Schedule Variance (SV(t)) and Schedule Performance Index (SPI(t)) for analysing a project's schedule status and performance. Follow on papers by Henderson described the results of retrospectively applying ES to a portfolio of six small projects managed using a "simplified" EVM approach where the preliminary conclusion reached was that the ES concept has validity [3] [4].

This paper describes the application of Earned Schedule by the author on a small scale but time critical Information Technology (IT) software development project. The ES indicators were actively used in conjunction with the traditional EVM and network schedule based measures to manage the project.

The critical path calculated completion dates after weekly status updates to the "logic driven" network schedule were tabulated and compared with the weekly ES predicted completion dates. Analysis of the differences occurred as part of the weekly schedule update and review process.

While care should be taken in generalising the results and specific experiences of this small scale project, the active use of ES has provided additional important insights into the behaviour and benefits of the ES metrics which could only come from "actual use". ES is shown to provide an important "bridge" between the EVM data and metrics and the "real" network schedule.

Earned Value and Earned Schedule Discussion

The basics of Earned Value are comprehensively documented in many public domain sources [4] [5] [6] [7]. [1] The proposed Earned Schedule (ES) extension to Earned Value Management (EVM) is described by Lipke [1] and Henderson [2] [3].

The Scheduling Challenge

Project scheduling is a complex, difficult and challenging task. Table 1 provides a summary of the characteristics of the initial baseline schedule for "Example Project #1", the case study project used in this paper. This project was a very small but time critical software development and enhancement project upon which the launch of a revenue generating marketing campaign in a commercial organisation was dependent.

Even on a small scale project such as this, preparing a realistic project schedule is dependent on multiple, often complex factors including accurate:

- Estimation of the tasks required, task durations and resources required to complete the identified tasks

- Identification and modelling of task and other logic and milestone dependencies impacting the execution of the project.

As projects grow from small projects into large projects and programs, scheduling requirements becomes exponentially more complex. Additional factors, including the need to integrate schedules between "master" and "subordinate" schedules, often across multiple tiers of activities and organisations contributing to the overall program of work also becomes an essential requirement for producing a useful integrated master schedule.

	Initial Baseline Schedule	Final Schedule	Schedule Growth
Line Items	88	99	11.1%
Summary Tasks	26	29	10.3%
Milestones	8	8	0.0%
Tasks	54	62	12.9%
Predecessors	68	75	9.3%
Critical Path Tasks	12	N/A	N/A

Table 1: Example Project #1: Network Schedule Metrics

To further compound the complexity of the scheduling challenge, once an initial schedule baseline has been established, progress monitoring inevitably results in changes to the schedule. Change result from changes to task and activity durations caused by "actual performance" not conforming to plan, additional unforeseen activities being added and logic changes as a result of corrective actions to contain slippages or improved understanding of the work being undertaken. Other planned changes also contribute to schedule modifications over time. Table 1 provides a summary of the "schedule growth" metrics which occurred on Example Project #1. This is as an illustrative example of the size and scale of the schedule changes which can occur from the initial baseline schedule, even on a very small scale project.

Using the network schedule as the basis for schedule sensitivity, "what if" and risk analysis is also a difficult task dependent on many estimating and scheduling logic assumptions which can be difficult to develop and even more difficult to validate.

In the common circumstance of projects being "time critical" publishing "what if" schedule analysis which projects dates later than the committed dates creates an impression of management acceptance of schedule slippages, particularly amongst the teams responsible for performing the actual work. The usual management preference is for work to be scheduled and tracked against more "aggressive" delivery timelines to support the perception that every effort is being made to achieve the "required" delivery deadlines.

One often attempted (in these difficult circumstances) "solution" to this dichotomy is to maintain "two" schedules:

- The "internal" schedule with the more aggressive dates and deadlines; and
- A "more realistic" schedule which is used as the basis for management reporting of schedule commitments "up the management reporting chain".

Unfortunately, the usual result of a "two schedule" approach is increased confusion and complexities being introduced into the schedule update process including the understandable perceived need to "reconcile" the two schedules. These factors compound the scheduling issues and difficulties rather than contributing to resolving them. If the decision to work to a single "schedule of record" is not implemented by the Project Manager, resolution will often occur via senior management edict.

An improved solution is to explicitly include "schedule contingency" which provides a "Schedule Reserve" in the single project "schedule of record" to protect committed key or important milestone delivery dates. This approach requires an increased level of management sophistication which including a preparedness to allow Schedule Reserve to be explicitly and visibly declared in the schedule.

A useful addition to the project management profession and project management practitioners would be a set of macro level indicators and predictors which, ideally, could be derived separately from the network schedule. These metrics would provide a means for comparison and validation of the measures and predictors provided by the network schedule. An independent predictor of project duration would be a particularly useful metric, due to the importance attached to "on time" completion of projects.

Since EVM provides such indicators for cost, the Independent Estimate At Completion (IEAC) predictive formulae, it probably not surprising that EVM practitioners have periodically requested and proposed similar performance predictors for schedule. [3]

Earned Schedule

Lipke has developed and described the concept of "Earned Schedule". ES creates time or duration based indicators which are used instead of units of cost or value for measuring schedule performance. As explained by Lipke:

The cumulative value of ES is found by using BCWP to identify in which time increment of BCWS the cost value occurs. The value of ES then is equal to the cumulative time to the beginning of that increment (e.g., months) plus a fraction of it. The fractional amount is equal to the portion of BCWP extending into the incomplete time increment divided by the total BCWS planned for that same time period. [1] [2]

From the ES measurement the following cumulative time based metrics have been constructed:

Schedule Variance (t): SV(t) = ES – AT

Schedule Performance Index (t): SPI(t) = ES / AT

where AT is the actual time in the time-based unit of measure (e.g. weeks or months) being utilised. These metrics behave in an analogous manner to the EVM cost indicators, Cost Variance (CV) and Cost Performance Index (CPI).

Predictive Uses of Earned Schedule

Henderson [3] suggested techniques which can be used to independently calculate estimates of project duration and the project completion date.

The first technique calculates an Independent Estimate at Completion (time) [IEAC(t)] [3] by using:

IEAC(t) = PD / SPI(t)

where PD is the Planned Duration.

The development of the Planned Duration for Work Remaining PDWR concept and measure [4] has provided for a "long form" IEAC(t) formula:

IEAC(t) = AT + (PD – ES cum) / PF

where PF is a Performance Factor. This formula provides for the possibility of schedule performance factors other than SPI(t) to be developed and utilised.

The Independent Estimate of Completion Date (IECD) for the project is calculated as:

IECD = Project Start Date + IEAC(t)

The behaviour of the IEAC(t) and IECD is consistent with the EVM cost based equivalent, the IEAC.

Earned Schedule in Action

Example Project #1 was managed using the simplified EVM methods previously described [3], extended to include the ES measures and indicators. Calculation of the ES IEAC(t) and IECD predictors have been simplified and are to a precision of 1 week.

A resource loaded, logic driven network schedule was created using Microsoft Project 2002 during the project planning and estimating phase. The Microsoft Project calculated time phased Planned Values for the initial baseline schedule at project level was "copied and pasted" into the Microsoft Excel EVM template to create the Performance Measurement Baseline (PMB). This approach achieved a high and very direct level of cost and schedule integration for the project.

Regular weekly schedule updates occurred from week 3 with particular attention being placed on:

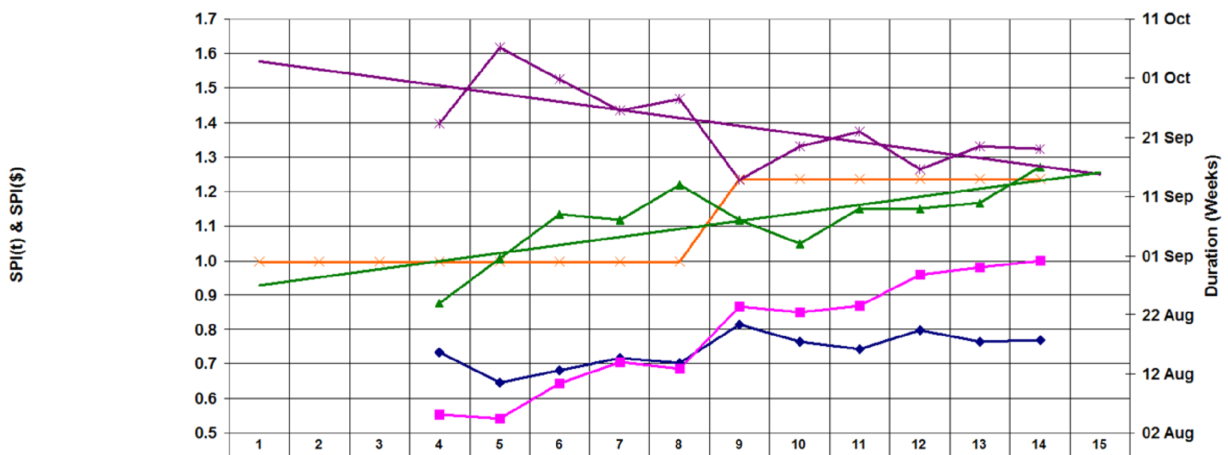
- Accurate task level percentage work completion updates. The project level percentage work completion (cumulative) was calculated by Microsoft Project. This value was transferred to the EVM and ES template and used to derive the progressive Earned Value (cumulative) measure weekly;
- Schedule review with a particular focus on critical path analysis. Schedule updates occurred as needed with revised estimates of task duration and changes to network schedule logic, particularly where this was needed to facilitate schedule based corrective action; and

- Actual costs were obtained from the corporate financial accounting system and entered into the EVM template as they became available weekly.

The critical path calculated and ES IECD predicted completion (production implementation milestone) dates were tracked weekly in a worksheet and chart developed specifically for this purpose as shown in Figure 1. The trend lines were superimposed during post project completion review and analysis.

SPI(t) and SPI($) are graphed on the first y axis with the Planned Completion Date, IECD and critical path calculated completion dates graphed against the second y axis. Use of the IECD, rather than the IEAC(t) was found to be more intuitive as it facilitated direct comparative analysis to the critical path calculated completion date.

While generally accepted methods of portraying ES information are still to be developed, this chart proved to be particularly useful for summary and comparative schedule status analysis. All the information required to conduct the summary analysis of schedule status and schedule performance trends was on a single page.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SPI(t) cum				0.73	0.65	0.68	0.72	0.70	0.82	0.77	0.74	0.80	0.77	0.77	
SPI($) cum				0.55	0.54	0.64	0.71	0.69	0.87	0.85	0.87	0.96	0.98	1.00	
Planned Completion Date	31 Aug	31 Aug	31 Aug	31 Aug	31 Aug	31 Aug	31 Aug	31 Aug	14 Sep	14 Sep	14 Sep	14 Sep	14 Sep	14 Sep	
IECD (PD/SPI(t))				23 Sep	06 Oct	30 Sep	25 Sep	27 Sep	13 Sep	19 Sep	21 Sep	15 Sep	19 Sep	19 Sep	
Critical Path Completion				24 Aug	31 Aug	08 Sep	07 Sep	13 Sep	07 Sep	03 Sep	09 Sep	09 Sep	10 Sep	16 Sep	

Time (Weeks)

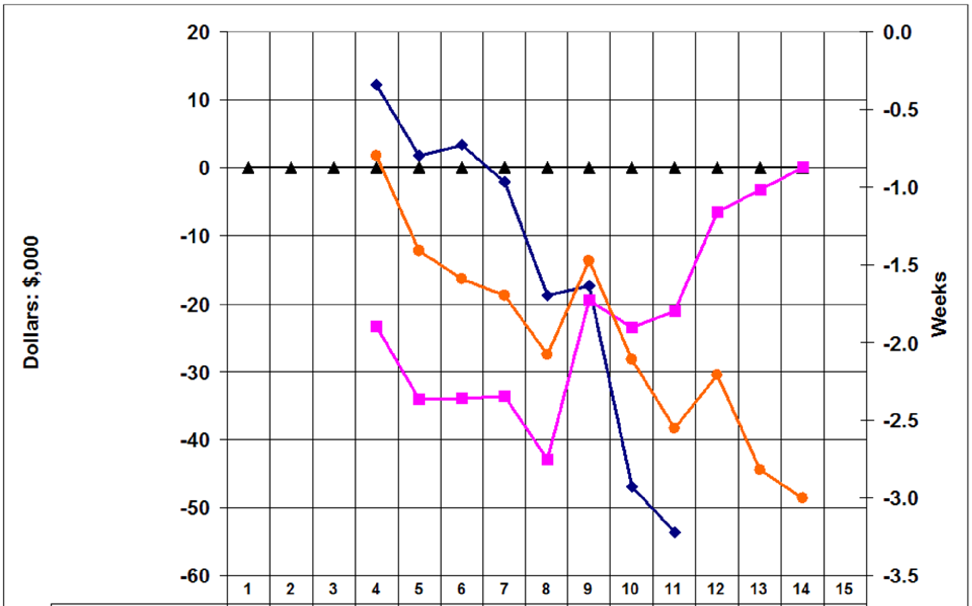
Figure 1: Example Project #1: History of Earned Schedule and Critical Path Method Predicted Completion Dates, SPI(t) and SPI($) Indicators

Schedule Analysis

The initial finding from the analysis is that the IECD consistently predicted later completion dates than the critical path. The trend lines added to the critical path calculated completion dates depict an “early finish” project with deteriorating schedule performance while the IECD trend line depicts a “late finish” project with improving schedule performance over time.

This was contrary to the initial expectation that the that the critical path would drive the more pessimistic predicted completion dates and ES IECD would produce the more optimistic predicted outcomes because ES cannot take into account critical path information as it is derived from the EVM, rather than schedule data.

The "critical question" occurred in week 8 where the critical path calculated completion date deteriorated and the weekly ES IECD improvement trend did not continue. The question was whether the more pessimistic ES IECD indicator and trend deterioration should be believed and reacted to. Analysis of the project status, correlated to the project schedule resulted in the conclusion that the ES IECD was, in this instance, the more credible predictor. Work was not being accomplished at the rate planned with no adverse contribution by critical path factors, such as externally imposed delays caused by "dependent milestone" slippages.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Target CV and SV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
CV cum				12.2	1.7	3.3	-2.1	-18.8	-17.3	-46.8	-53.5				
SV($) cum				-23.4	-34.1	-33.9	-33.6	-42.9	-19.5	-23.5	-21.0	-6.5	-3.2	0.0	
SV(t) cum				-0.8	-1.4	-1.6	-1.7	-2.1	-1.5	-2.1	-2.6	-2.2	-2.8	-3.0	

Figure 2: Example Project #1 Cost and Schedule Variances

Confirmation of this analysis was provided by SV(t) which showed consistent week on week schedule slippage (Figure #2) which was also considered consistent with the real project schedule performance. One reason was that a key project team member had been diverted to another project which contained functionality on which Example project #1 was dependent for delivery.

Another item noted is that the ES IECD trend from week to week was usually consistent with the critical path calculated completion date week on week trend. An adverse critical path calculated end date from week n to week n+1 was usually accompanied by a similar adverse trend in the IECD. The difference was that the IECD was trending from a more pessimistic starting position. Reasons for this were determined to include:

- Schedule updates concentrated on tasks in the current period with re-estimates of the completion dates for current tasks.
- Consistent with common schedule practice, there was no re-estimates of future critical path (and near critical path) tasks based on current and historic schedule performance at the task level to date.

In time critical projects especially, there is usually a reluctance to call schedule delays and slippages early. The laudable tendency is to apply additional effort to try and achieve the committed scheduled completion date.

In contrast, the SPI(t) performance factor used to calculate the IEAC(t) from which the ES IECD is derived does project future schedule performance based on the ES calculated time based schedule performance achieved to date. This explanation is consistent with the status at Week 8 of the:

- SV(t) negative variance of -2.1 weeks and SPI(t) of .7;
- Critical path calculated completion date of 13th September, a negative projected Variance At Completion (time) of -13 days or -1.86 weeks; and
- ES IECD projecting a 27th Sep completion date compared to a 31st Aug Planned Completion Date. This is a negative projected Variance At Completion (time) of -27 days or -3.9 weeks.

Based on the detailed analysis of the week 8 indicators and project status, an irrecoverable 2 week schedule slippage was communicated, with a revised delivery date of 14th September. A commitment to try and recover "if at all possible" was also made to deliver a more palatable message to management.

In an organisation where late communication of unavoidable schedule slippage was a repeatedly raised concern during the course of the project, the relatively early and proactive communication of slippage was actually appreciated.

Immediate corrective action was implemented which, based on the week 9 ES IECD predictor resulted in 2 weeks progress being achieved in 1 week. SV(t) improved from -2.1 weeks to -1-5 weeks in Week 9. The exact convergence of the ES IECD and the revised Planned Completion Date was coincidental as the extent of the progress achieved in week 9 was neither forecast nor expected.

It is also interesting to observe that in spite of the week 9 improvement in SV(t), the overall SV(t) trend continued to deteriorate until project completion. This highlights the difficulty in sustaining a continuously improving project performance trend over time and also demonstrates the increased utility of SV(t) for analysing schedule performance. SV($) was of limited utility as it was (broadly) commencing its inevitable trend in the latter stages of a project to 0 at project completion.

A decision was taken not to re-baseline the project but use the current baseline to track progress to the revised Planned Completion Date. While SPI($) also began its inevitable upward trend to 1.0 at project completion, SPI(t) also provided the important indicator, that in spite of the "significant" corrective action which occurred in week 9, overall schedule performance efficiency in ES terms remained in the .7 to .8 band to project completion. The project subsequently delivered on September 21, a one week delay to the revised commitment. The further delay occurred for reasons external to the project.

Observant readers will note that in Figure 2, CV data for weeks 12 to 14 inclusive is not recorded. The reason for this was a transfer to a new time recording system within the organisation. This situation inadvertently highlighted another benefit to ES which is that it has no calculation dependency on Actual Costs, the EVM metric for which the data most commonly lags in availability. Once the PMB is in place and the Earned Value measure is calculated, the ES measures and metrics are also available for schedule analysis.

Benefits and Conclusions

The opportunity to use ES on a small scale project provided additional insights into the behaviour and benefits of the ES metrics which could only come from "actual use". The ES metrics were found to be of considerable assistance and benefit in analysing and managing the schedule performance of time critical Example Project #1.

The time based measures and predictors of schedule performance greatly simplified the comparative analysis of the ES metrics and network schedule and critical path calculated completion date when compared to the use of the historic cost based (SV($) and SPI($). The value of ES in providing time based units of measure from EVM data should not be underestimated as metrics using common time based units of measure greatly simplified comparative analysis with the network schedule indicators.

Since the ES metrics are derived from the EVM data and not directly from the schedule many of the competing priorities and tensions associated with schedule management became "non issues". While ES in not a substitute for a properly constructed logic driven, resource loaded network schedule, issues associated with the management of "optimistic" schedule estimates and updates in a time critical project were avoided. The ES metrics provided an independent means of sanity checking the critical path predicted completion date prior to communicating overall schedule status to management.

It is anticipated based on this initial experience that the utility of ES will be of considerable value to the schedule management and analysis for large scale projects and programs because of the exponential increase in the network scheduling complexities which is both unavoidable and necessary on those programs and the correspondingly greater need and benefits from an independent means of sanity checking schedules of such complexity.

For these benefits to be realised and ES to become the "bridging technique" between EVM and the network schedule, the empiric validation of the ES theory to large scale projects and programs needs to be completed and ES updates incorporated into EVM software products.

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About the Author

Kym Henderson's Information Technology (IT) career features broad experiences covering, Project Management, Software Quality Assurance Management and Project Planning and Control. He has worked for a number of reputable IT companies across many industry sectors including commercial IT, Defence, Government, Manufacturing, Telecommunications and Financial Services. The focus has been large, complex project and corporate environments.

He has a Masters of Science (Computing) from the University of Technology Sydney. He has also received a number of awards including a Reserve Force Decoration (RFD) for 15 years efficient service as a commissioned officer in the Australian Army Reserve. He is currently the Education Director of the PMI Sydney Australia Chapter and is also a member of the PMI College of Performance Management.

Kym has extensive experience in "project recovery", where the use of simplified EVM techniques to assist in rapidly evaluating current project status, statistically predicting a likely range of project Costs at Completion and objectively measuring project progress to completion have proven invaluable.

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End Notes

1 The basic EVM measures are:

ACWP = Actual Cost for Work Performed
BCWP = Budgeted Cost for Work Performed (Earned Value)
BCWS = Budgeted Cost for Work Scheduled (Planned Values)

Cost Variance (CV) and Schedule Variance (SV) [$] are calculated as:

CV = BCWP - ACWP

SV = BCWP - BCWS

Cost Performance Index (CPI) and Schedule Performance Index (SPI) [$] are calculated as:

CPI = BCWP/ACWP

SPI = BCWP/BCWS

2 ES cum is equal to the number (N) of BCWS($) time increments BCWP($) exceeds plus a fraction of the next BCWS time increment. In equation form:

$$ES_{cum} = N + \frac{[BCWP (\$) - BCWS (\$)_{preceding\ period}]}{[BCWS (\$)_{current\ period} - BCWS (\$)_{preceding\ period}]}$$

where N is the number of BCWS($) time increments exceeded by BCWP($).

3 Adjustments to the nomenclature in this paper have occurred as a result of acceptance of the recommendation made at the PMI-CPM 2004 Conference held in Clearwater Beach Florida to standardize the ES naming conventions with the analogous EVM names and the use of a (t) for “time” suffix to distinguish the ES indicators.