Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data

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Abstract

The historical Earned Value Management (EVM) Schedule Variance (SV ($)) and Schedule Performance Index (SPI ($)) measures have peculiarities which create well-understood limitations in their use for analysing a project's schedule status and performance. Lipke has summarised these limitations and proposed the concept of "Earned Schedule" (ES) to address these issues in his article "Schedule is Different" [1]. ES aims to measure schedule performance using a time-based measure from which time based measures of Schedule Variance (SV (t)) and Schedule Performance Index (SPI (t)) metrics are derived. The ES concept is claimed to be analogous to Earned Value and can be used to calculate measures intended to be analogous to EVMs cost based counterparts.

I have retrospectively applied the ES measures proposed by Lipke to my small portfolio of six projects and subprojects managed using a "simplified" EVM approach. This paper shares the data and results of that study. The conclusion is that the ES concept has validity. The ES based schedule metrics more accurately portray a project's schedule performance compared to the EVM equivalents. It is concluded that the ES measures and metrics are expected to have utility similar to their cost based counterparts, the recognized strength of EVM, and a greater utility than their historic EVM based equivalents.

By extending EVM to include valid duration based measures of schedule performance, ES may be considered a "breakthrough" extension to Earned Value theory.

Earned Value Discussion

The basics of Earned Value are well and comprehensively documented in many public domain sources [2] [3] [4]. [1]

EVM introduces an additional measure of project performance to the familiar budgeted (BCWS) and actual costs (ACWP). This is a measure of the project's "physical progress" actually achieved, the Earned Value (BCWP). Variance metrics are calculated by reference to the Earned Value measure; Cost by reference to the calculated difference with ACWP and Schedule, by reference to the calculated difference from BCWS.

To facilitate variance analysis a common unit of measure for all of these basic metrics is essential. Historically this has been a unit of "value" or "cost", typically either dollars or hours. Herein lies the root cause of the peculiarities associated with Earned Value and the EVM Schedule Variance:

1. Earned Value is algebraically constrained by its “budgeted costs” calculation reference. This means the Earned Value will always approach equality with BCWS as work is performed irrespective of issues associated with the project’s actual duration; and
2. SV ($) is not duration-based measure, as the name implies.

Abba [5] and others have correctly pointed out that SV ($) is really a measure of the volume of work accomplished versus the volume of worked planned which, with the benefit of hindsight, might have been better called an “Accomplishment Variance”.

While this correctly explains the behaviour of SV ($), the periodically expressed desire has continued within the EVM community for duration based measures of schedule performance and variance which practitioners could apply in a manner analogous to EVMs cost based counterparts.

Earned Schedule

Lipke, expanding from earlier work described by Fleming [2] has developed and described the concept of “Earned Schedule”. ES is claimed to be analogous to Earned Value except that a time or duration based measure of schedule is used instead of cost 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]

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. [2] Lipke has deliberately constructed these metrics to behave in an analogous manner to the EVM cost indicators, CV and CPI.

Project Data

I have used a simplified EVM approach for the management of Information Technology (IT) projects, in the commercial sector for more than 7 years. Earned Value (BCWP) is derived using a percentage of project completion method in which percentage (work) complete is derived from a weekly process of task level updates to the project schedule by the project team. EVM data and measures are calculated and graphed using Microsoft Excel based spreadsheet templates developed for these purposes. The spreadsheets are designed to facilitate EVM based project status updates weekly and roll-up to monthly levels views for formal project status reporting. The application of EVM is limited to the direct labour component of the project.

A summary of the portfolio of projects to which ES has been applied is summarised in Table 1.

	Project	Category	Budget at Complete	Cost at Complete	Planned Duration	Actual Duration
			$ Australian		Weeks	
1	Commercial IT Infrastructure Expansion Project Phase 1 [Table Note 1]	Late Finish	$158,899	$307,738	20	34
2	Commercial IT Infrastructure Expansion Project Phases 2 & 3 [Table Note 2]	Early Finish	$112,000	$53,745	25	22
3	Commercial IT Infrastructure Expansion Project Phases 1, 2 & 3 total (overall project) [Table Note 3]	Early Finish	$270,899	$361,483	49	46
4	Commercial IT Software Development Project	Early Finish	$145,085	$143,575	19	13
5	Commercial IT Infrastructure Replacement Project (Re-baselined) [Table Note 4]	Late Finish	$2,426,094 ($3,819,570)	$3,870,048	65 (81)	83
6	Commercial IT Software Interface Development sub-project (part of #5)	Late Finish	$219,200	$409,470	9	23

Note 1: The real years of project performance in Figure 5 has been changed to maintain project anonymity.
Note 2: The real years of project performance in Figure 6 has been changed to maintain project anonymity.
Note 3: The difference in cumulative planned duration for all phases is explained by a 4 week gap between the completion of Phase 1 and commencement of Phases 2 / 3 in the baseline schedule
Note 4: 1) Contract Budget Baseline for labour $2,426,094 excluding risk (management reserve). This was adjusted by Change Orders and a risk re-allocation for a labour cost overrun to the re-baselined BAC of $3,819,570
2) Contract Budget Baseline Planned Duration: 65 weeks
3) Re-baselined Planned Duration as subsequently adjusted by Change Orders: 81 weeks
4) Actual duration to completion: 83 weeks

Table 1: Summary of Projects to Which Earned Schedule Applied – Direct Labour Components

This study was undertaken to independently test the validity of the ES concept and associated metrics described by Lipke using my own real project data. The purpose was to determine whether it would be of benefit to incorporate ES into my own project management and EVM practice.

Study Description

The use of “spreadsheet” template based EVM facilitated the ease of retrospective inclusion of the ES measures and metrics into my portfolio of EVM completed projects. The method adopted for the study was to:

1. Calculate the time phased ES measures and metrics as described above.
2. Incorporate SV (t) into a standard EVM CV and SV ($) graphical report on a secondary y axis and compare the behaviour of SV (t) with SV ($)

3. Incorporate SPI (t) into a standard EVM CPI and SPI ($) graphical report and compare the behaviour of SPI (t) with SPI ($)
4. Analyse the results obtained
5. Consider additional applications for ES.

Late Finish Projects

Figure 1 provides the CV cum, SV ($) cum and SV (t) cum for an example "late finish" project. EVM measures and metrics were first calculated in Week 11 after I assumed project management responsibility. Figure 1 displays the projects CV and SV ($) on the first y-axis in dollars and the SV (t) on the second y-axis in weeks.

SV ($) and SV (t) show a generally strong correlation until week 19. In Week 20, which was the week of the project's scheduled completion an externally imposed (client) delay completely halted nearly all project progress until resolution. This occurred in Week 26.

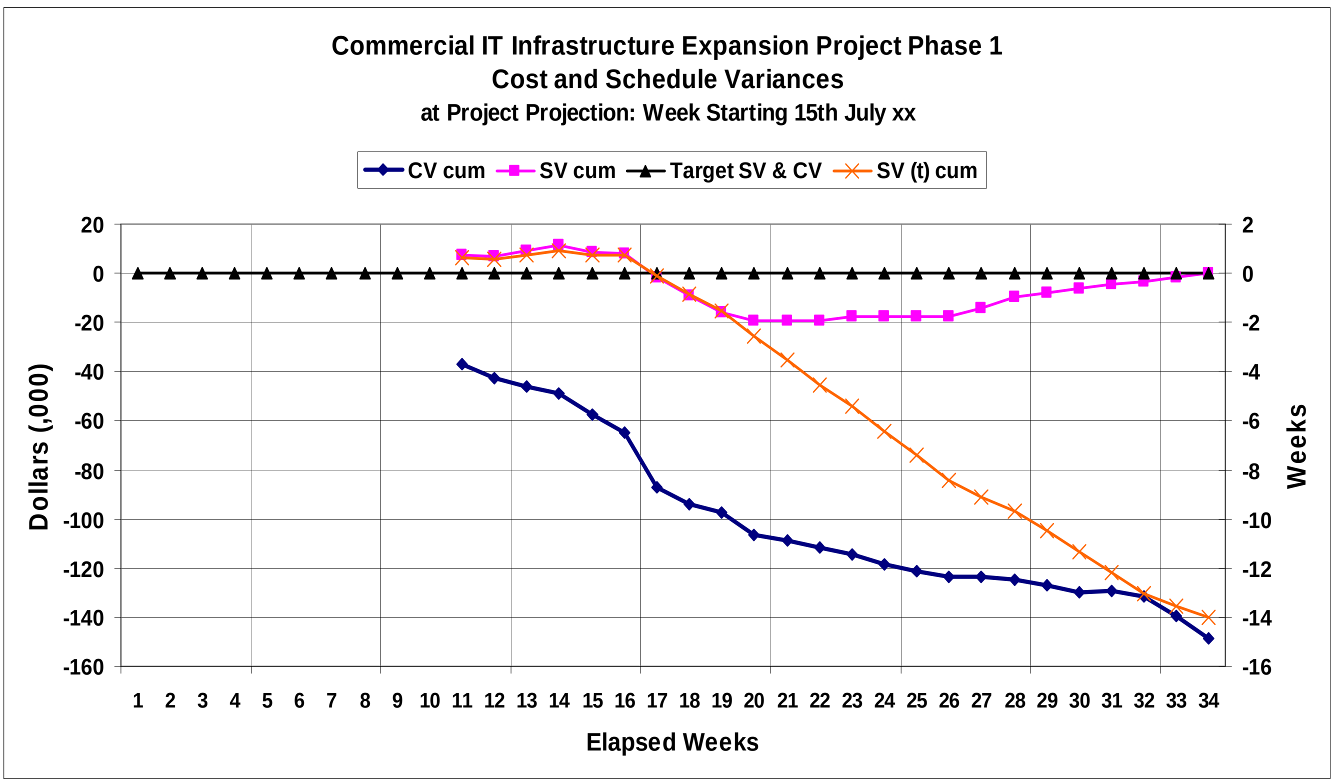


Figure 1: "Late Finish" Project 1 Cost and Schedule Variances

SV ($) remains "static" at around –$17,500 in spite of the week on week real schedule delay being experienced before trending upwards to its inevitable conclusion of $0 at project completion after work recommenced.

This example illustrates the breakdown of the utility of the SV ($) as BCWS remained constant because the planned completion date for the project (week 20) had been exceeded. This also meant that SV ($), which is calculated by reference to BCWS, also remained static in spite of the week on week real schedule delay being experienced during that period.

In contrast SV (t) correctly calculates the projects real week on week schedule delay and the projects actual –14 week schedule delay at completion. SV (t)'s accurate portrayal of the project's real schedule status is clearly of greater management utility than the status shown by SV ($). The same schedule performance trends and conclusions can be obtained by comparing the SPI (t) and SPI ($) in Figure 2 below.

The behaviour of SV (t) and SPI (t) have been analogous to and consistent with their EVM cost counterparts. The key benefit derived from using ES is that SV (t) is not algebraically constrained by reference to BCWS is illustrated.

It should also be noted that the adverse schedule trend shown by both SV ($) and SV (t) from weeks 16 to 19 is considered to accurately reflect the projects actual schedule performance during that period.

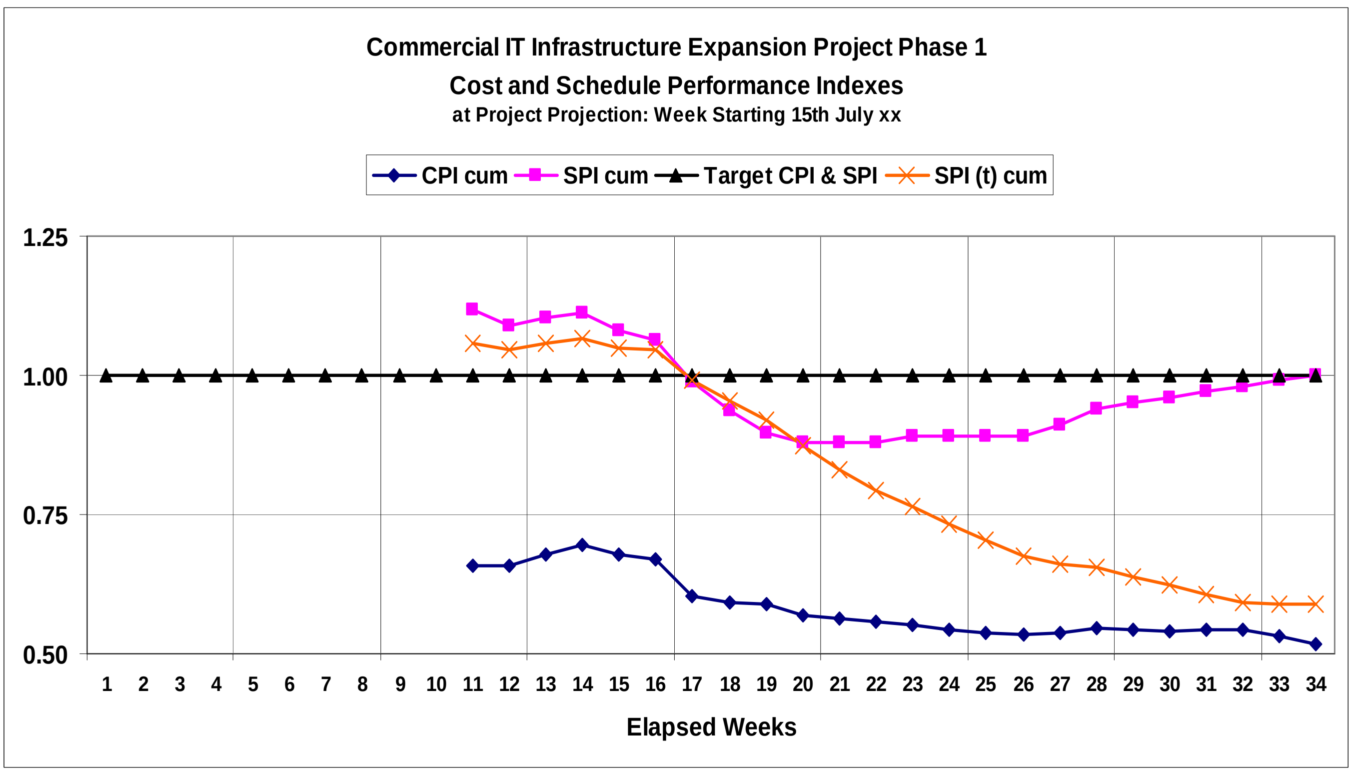


Figure 2: "Late Finish" Project 1 Cost and Schedule Performance Indexes

Data from the other "late finish" projects in Table 1, provided in the Appendix, consistently confirm the findings described.

Early Finish Projects

Figure 3 provides the CV cum, SV ($) cum and SV (t) cum for an example "early finish" project. The "early warning" provided by EVMs costs and schedule metrics, for the project shown in Figure 1 assisted in initiating negotiations and achieving client agreement to combine two upgrade offerings to the deployed system into a single follow-on project.

In contrast to the Figure 1 "late finish" example, SV ($) and SV (t) show a strong correlation over the life of the project.

The strength of this correlation is even more apparent when comparing SPI ($) and SPI (t). This project also experienced an externally imposed delay between weeks 16 and 19, prior to completing 3 weeks ahead of schedule.

However, both SV ($) and SV (t) accurately portray the delay period, SV (t) providing the advantage of calculating the delay as a measure of duration.

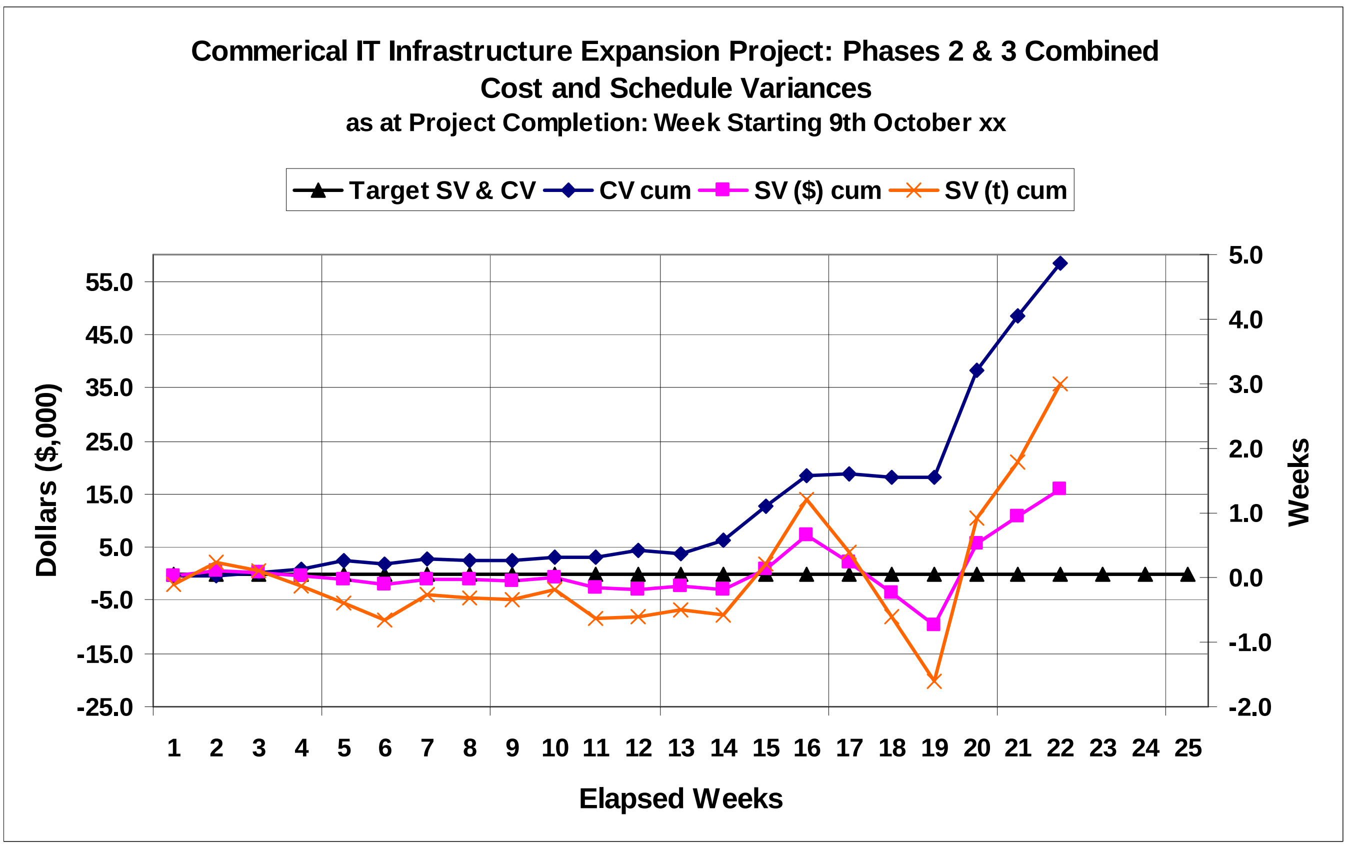


Figure 3: Early Finish Project 2 Cost and Schedule Variances

In the case of Early Finish projects, the ES metrics SV (t) and SPI (t) have behaved with remarkable consistency compared to their historic EVM counterparts.

Data from the other "early finish" projects provided in the Appendix are consistent with the findings described above.

Other Applications of ES

Lipke has described techniques, using ES, from which independently calculated estimates of project duration and the project completion date can be derived. The first technique calculates an Independent Estimate of (project) Duration (IED) by using:

IED = Planned Duration / SPI (t)

The second technique calculates an Independent Estimate of Completion Date (IECD) for the project. IECD may be calculated as:

IECD = Project Start Date + IED

The behaviour of the IED and IECD is analogous to the EVM cost based equivalent, the Independent Estimate at Compete (IEAC).

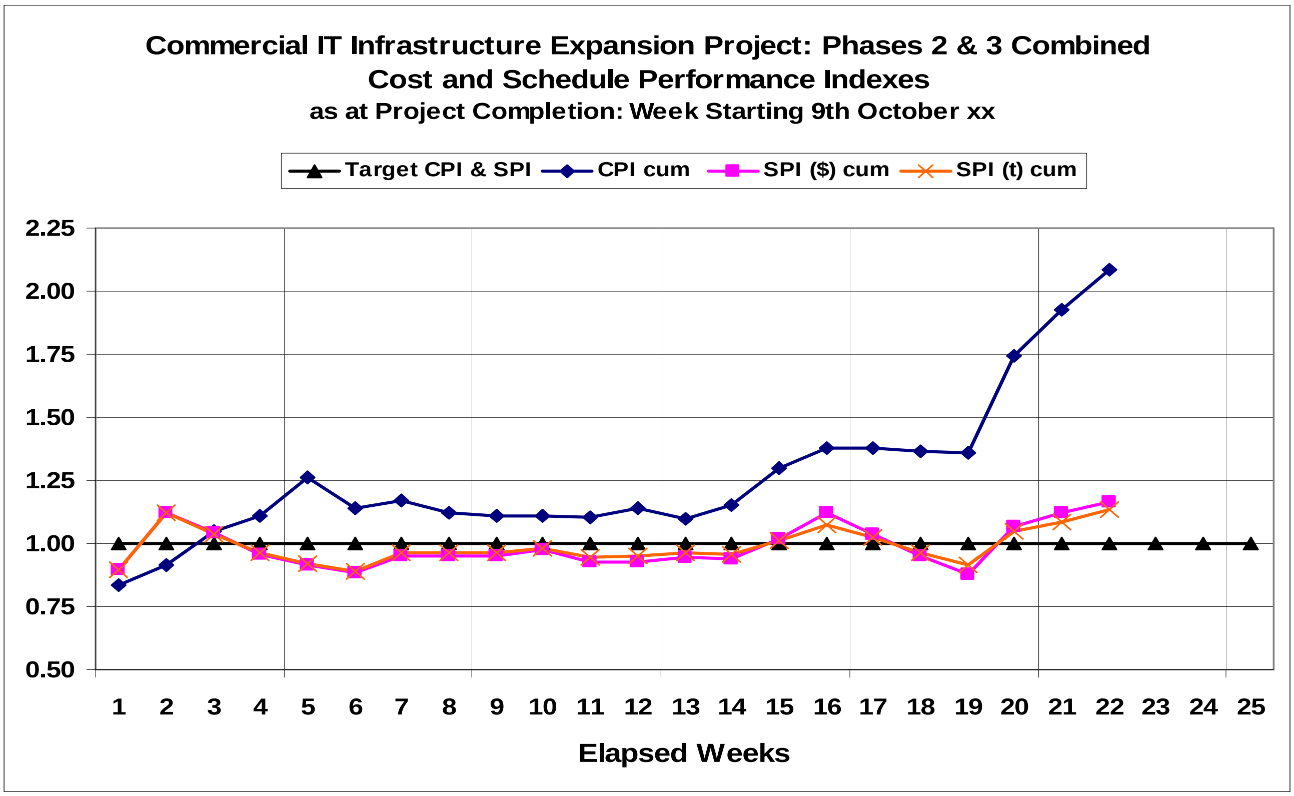


Figure 4: "Early Finish" Project 2 Cost and Schedule Performance Indexes

Some EVM practitioners, including Reynolds, have (pre ES) periodically suggested the following formula as means of deriving an IED. [3]

IED = Planned Duration / SPI ($)

It can now be seen that in cases where SPI ($) and SPI (t) behave consistently such a measure may have produced the "surprisingly accurate" results reported.

A significant problem with using SPI ($) as a performance factor for calculation of the IED, pre ES, would have been the lack of certainty in knowing whether or not the SPI ($) metric was still reliable. This is sometimes referred to as "the grey area", the period where the project manager cannot be sure of whether or not the SPI ($) metric should be believed and whether or not to react to it.

Simplified calculations of the IED and IECD using a Microsoft Excel template with a precision to the week are included in Figure 5.

Figure 5 shows potential uses of ES metrics in providing periodic calculations of the IED and IECD over time using a "late finish" project example. These metrics could be used to sanity check "real schedule" measures and as a means of detecting schedule performance trends over time. Both the IED and IECD accurately portray the impact of the week on week schedule delay experienced from weeks 19 to 26.

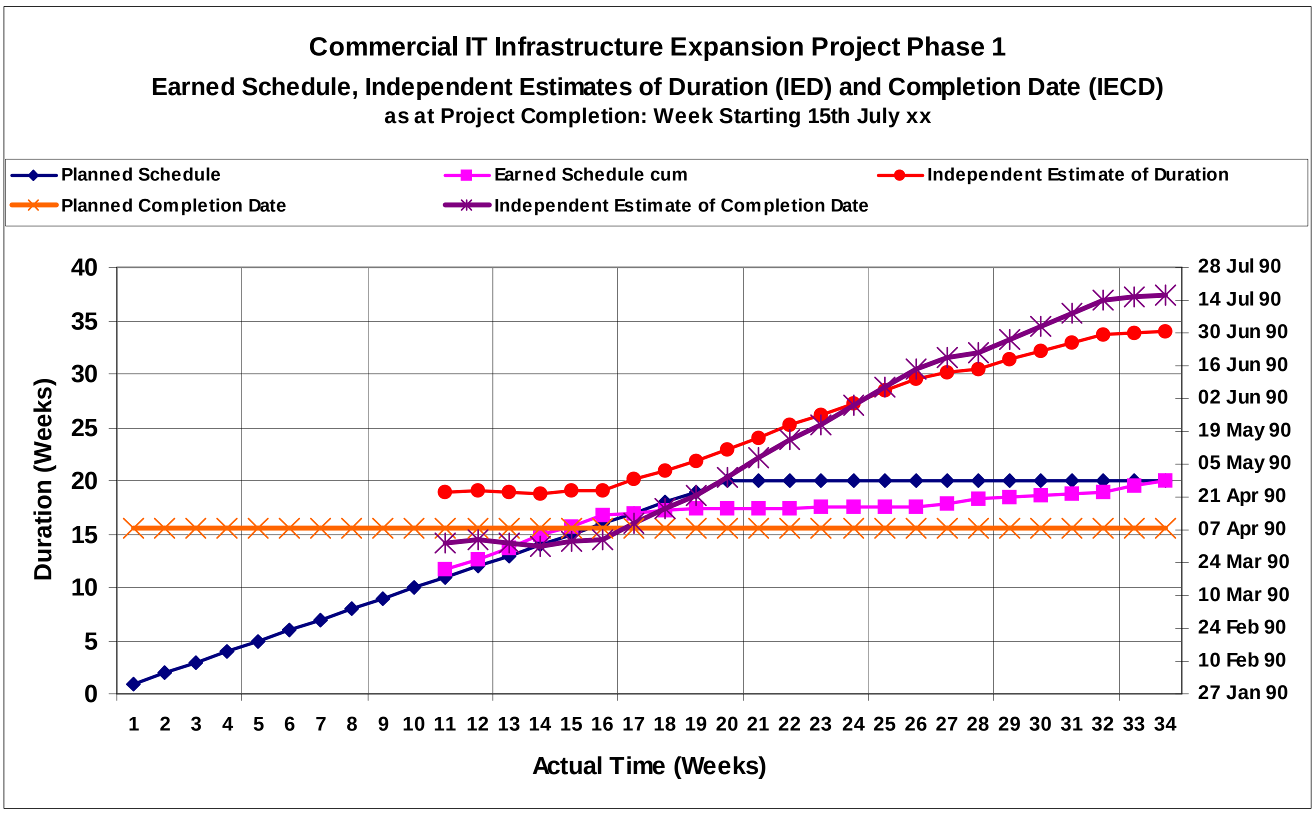


Figure 5: "Late Finish" Project 1 Weekly ES, IED and IECD Metrics

Lipke has advised that calculating the IED in planned workdays and entering the IED into the project schedule where the calendar has been set-up to include non working days such as public holidays will achieve the most precise estimate of the IECD.

Figure 6 shows the use of ES metrics in providing periodic calculations of the IED and IECD over time using an "early finish" project example. Both the IED and IECD accurately portray the impact of the week on week schedule impact during the period of delay experienced from Weeks 16 to 19 and the early project completion.

Possible Use of SPI (t) as an IEAC Performance Factor

Christensen [3] citing earlier work by Fleming and Koppelman suggests that SPI [($)] "*is useful for identifying schedule problems, especially when used with critical path information*" and "*Because schedule problems are often resolved by additional spending, an adverse SPI [($)] is also predictive of later cost problems.*"

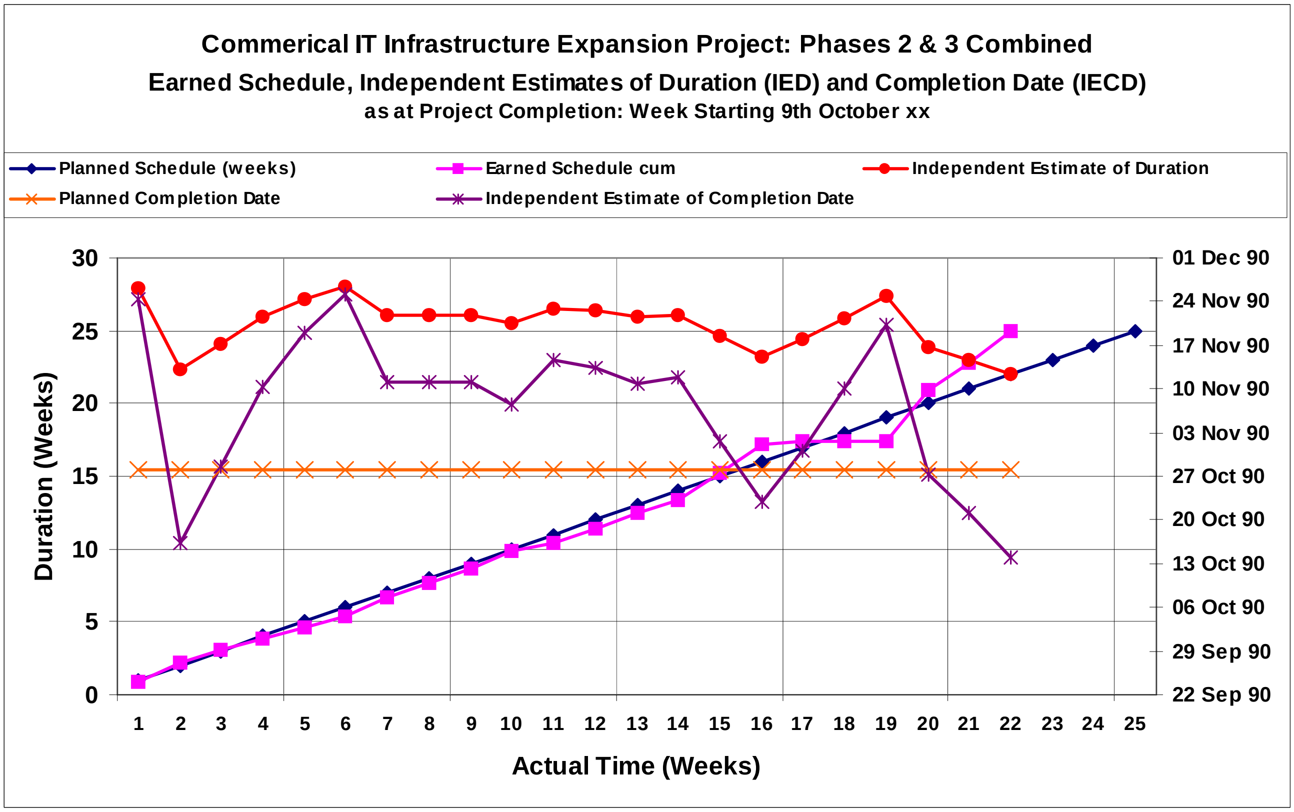
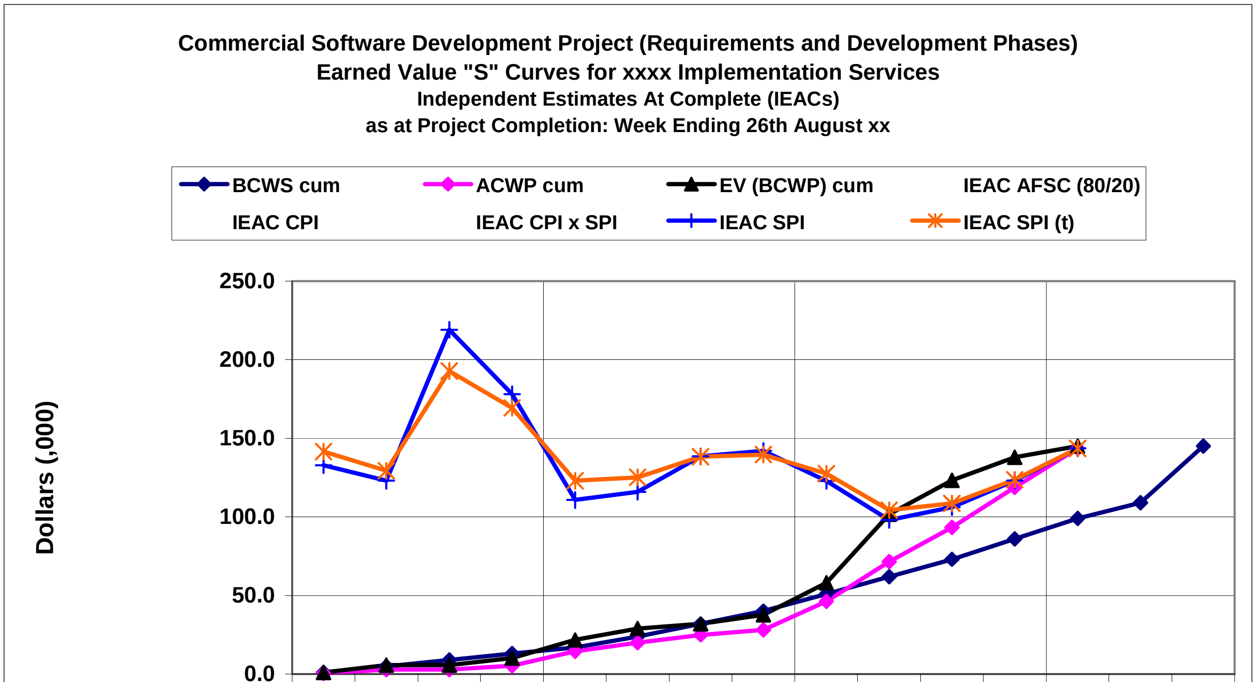


Figure 6: "Early Finish" Project 2 Weekly ES, IED and IECD Metrics

Christensen [4] used the results from the CPI, SPI ($) and combinations of the CPI and SPI ($) to determine a range of IEACs using data from the A-12 Avenger cancellation as the case study example. As SPI (t) has been shown to more accurately predict project schedule performance, especially in the case of late finish projects where SV ($) and SPI ($) loses utility, SPI (t) may offer greater utility as a performance factor for IEAC calculations, particularly when compared to SPI ($).

Figure 7 provides the periodic IEAC calculations for an example "Early Finish" software development project in which the SPI ($) and SPI (t) fluctuated considerably as a result of significant schedule compression. IEACs have been calculated weekly using the performance factors referred to by Christensen and SPI (t). IEAC SPI ($) and IEAC SPI (t) are graphed for comparative analysis.

As I have insufficient data for determining whether SPI (t) offers improved predictive utility for IEAC calculations, this is a possible use of the ES SPI (t) metric in which further research would be of benefit.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	19
BCWS cum	1.0	5.0	9.0	13.0	17.0	24.0	32.0	40.0	51.0	62.0	73.0	86.0	99.0	109.0	145.1
ACWP cum	0.5	2.9	2.9	5.3	14.4	20.0	24.9	28.2	46.3	71.5	93.3	118.6	143.6		
EV (BCWP) cum	1.1	5.8	5.8	10.2	21.8	29.0	31.9	37.7	58.0	101.6	123.3	137.8	145.1		
IEAC AFSC (80/20)	79.0	79.0	83.6	85.2	98.8	103.0	117.4	113.6	117.0	101.2	108.9	124.4	143.6		
IEAC CPI	71.8	72.7	72.7	75.7	96.3	100.2	113.3	108.5	115.7	102.1	109.8	124.9	143.6		
IEAC CPI x SPI	66.0	63.0	111.1	95.4	78.4	86.4	113.5	113.4	107.3	90.2	103.1	122.5	143.6		
IEAC SPI	132.9	122.9	218.9	178.0	110.8	116.0	138.4	142.1	122.8	98.0	106.2	123.2	143.6		
IEAC SPI (t)	141.4	129.5	192.8	169.4	123.0	125.1	138.3	139.5	127.5	104.3	108.5	123.6	143.6		

Figure 7: “Early Finish” Project 4 Weekly IEAC Metrics

Summary and Conclusions

The retrospective analysis of ES using my own EVM project’s 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) when compared to their historic EVM counterparts.

Lipke’s assertion that *“The application of Earned Schedule provides a set of schedule indicators, which behave correctly over the entire period of project performance”* has, using this sample of projects, been confirmed. 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 project examples.

Recommendations

By extending EVM to include valid duration based measures of schedule performance, ES may be considered a "breakthrough" extension to Earned Value theory. Due to their potential significance, these conclusions should be validated with a large-scale follow on study in which ES is retrospectively applied to a broad portfolio of completed EVM projects data.

In the meantime, EVM practitioners should consider applying ES to their own project management practice so as to increase the ES body of knowledge and derive the benefits ES appears to offer with respect to improved measures of schedule performance.

References

1. Lipke, Walter, *Schedule is Different*, The Measurable News, March 2003
2. Fleming, Quentin, & Koppelman, Joel, *Earned Value Project Management 2nd ed*, Upper Darby, PA: Project Management Institute, 2000
3. Christensen, David, Ph.d, *The Costs And Benefits Of The Earned Value Management Process*, Acquisition Review Quarterly—Fall 1998
4. Christensen, David, Ph.d, *Using The Earned Value Cost Management Report To Evaluate The Contractor's Estimate At Completion*, Acquisition Review Quarterly—Summer 1999
5. Abba, Wayne, *Emerging Ideas, Relating EVM to "Real" Schedules*, unpublished presentation

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, and Telecommunications. The focus has been large, complex project 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:

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

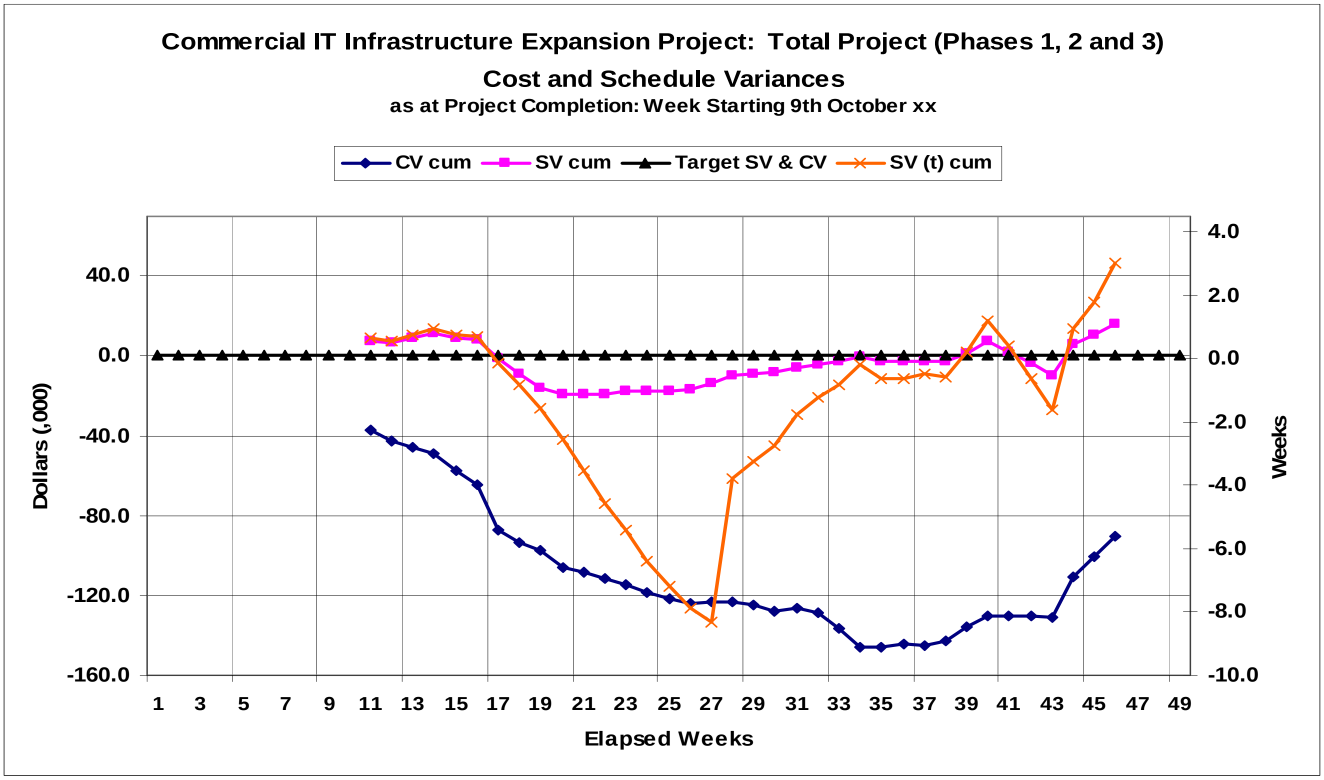
where N is the number of BCWS($) time increments exceeded by BCWP($).

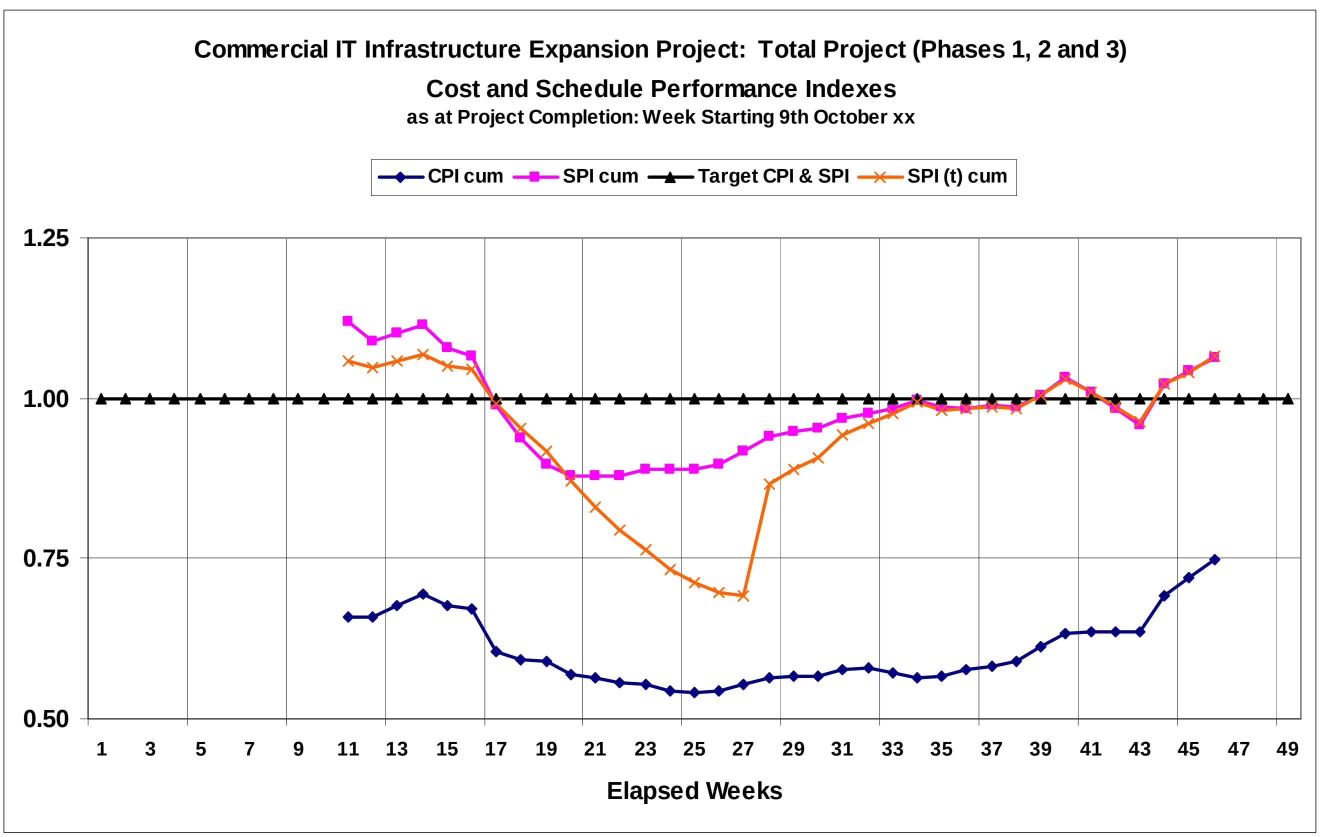
3. As one example; in response to a question posted on the Office of the (US) Secretary of Defense EVM website noteboard on how to use EVM to estimate the end date of the project, Mike Reynolds posted the following reply on 16th March 2002:

I agree with Wayne [Abba] that the best method is to use the scheduling tool to estimate an end date. This will allow for changes in the critical path, and activity slippage to drive a revised end date.
However, another tool I have used ***to develop a calculated end date is divide the elapsed duration of the baseline schedule by the SPI [$].*** *This approach is analogous to the EAC calculation using BAC/CPI. For example, if the ED was 60 Days, and your SPI is .85, a revised duration of 70.6 days is forecast.* ***It often surprises me how closely this algorithm comes to matching the forecast date from the working schedule (emphasis added).***

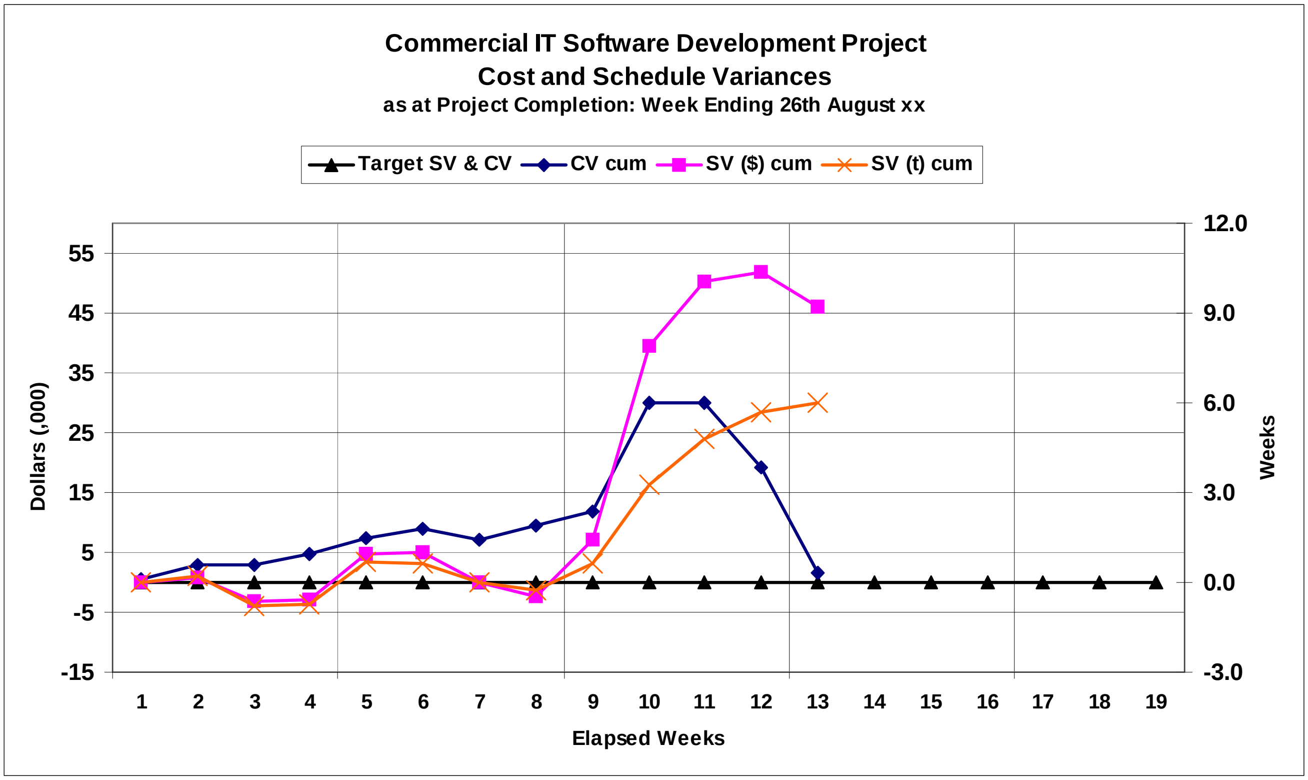
Appendix 1: Additional Earned Schedule Projects Data

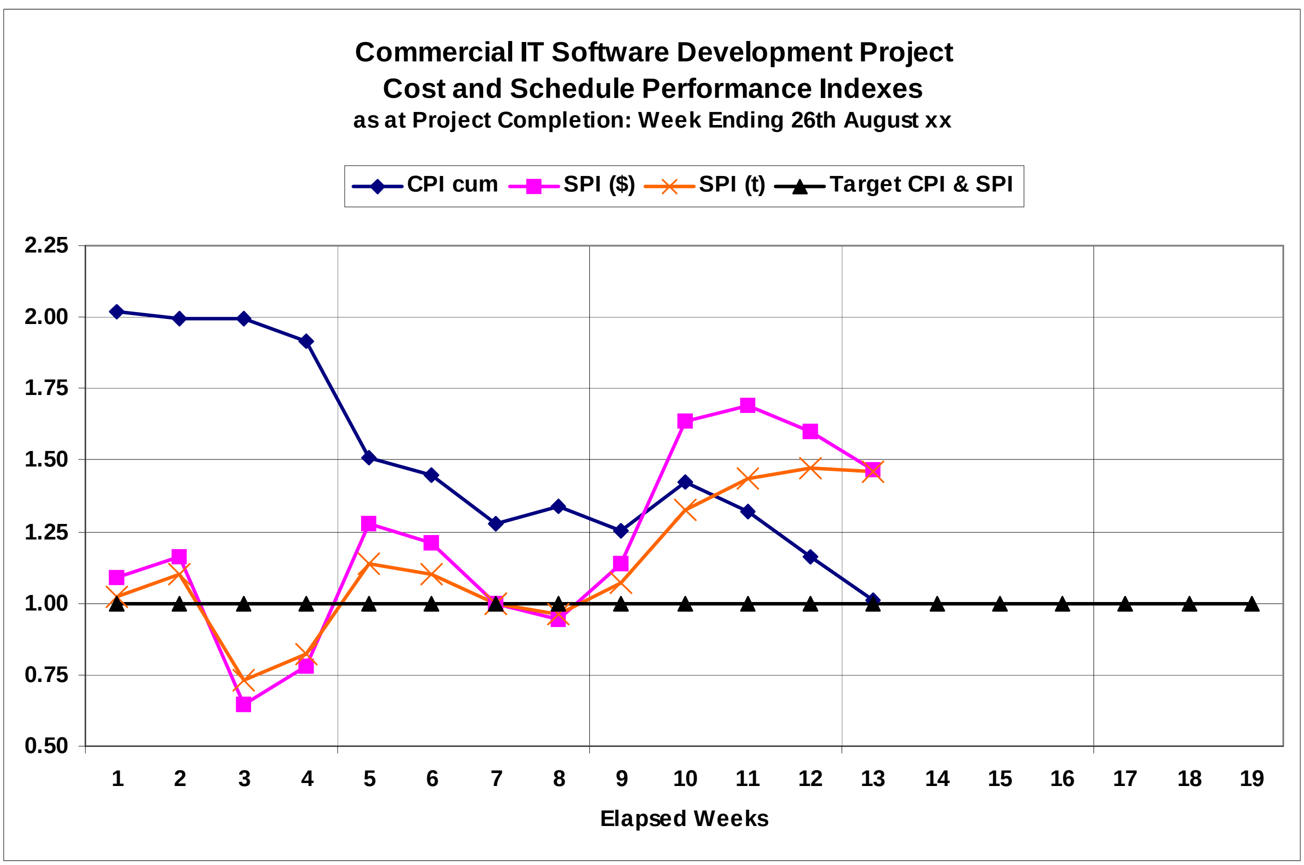
Project 3: Early Finish Commercial IT Infrastructure Project: Total Project



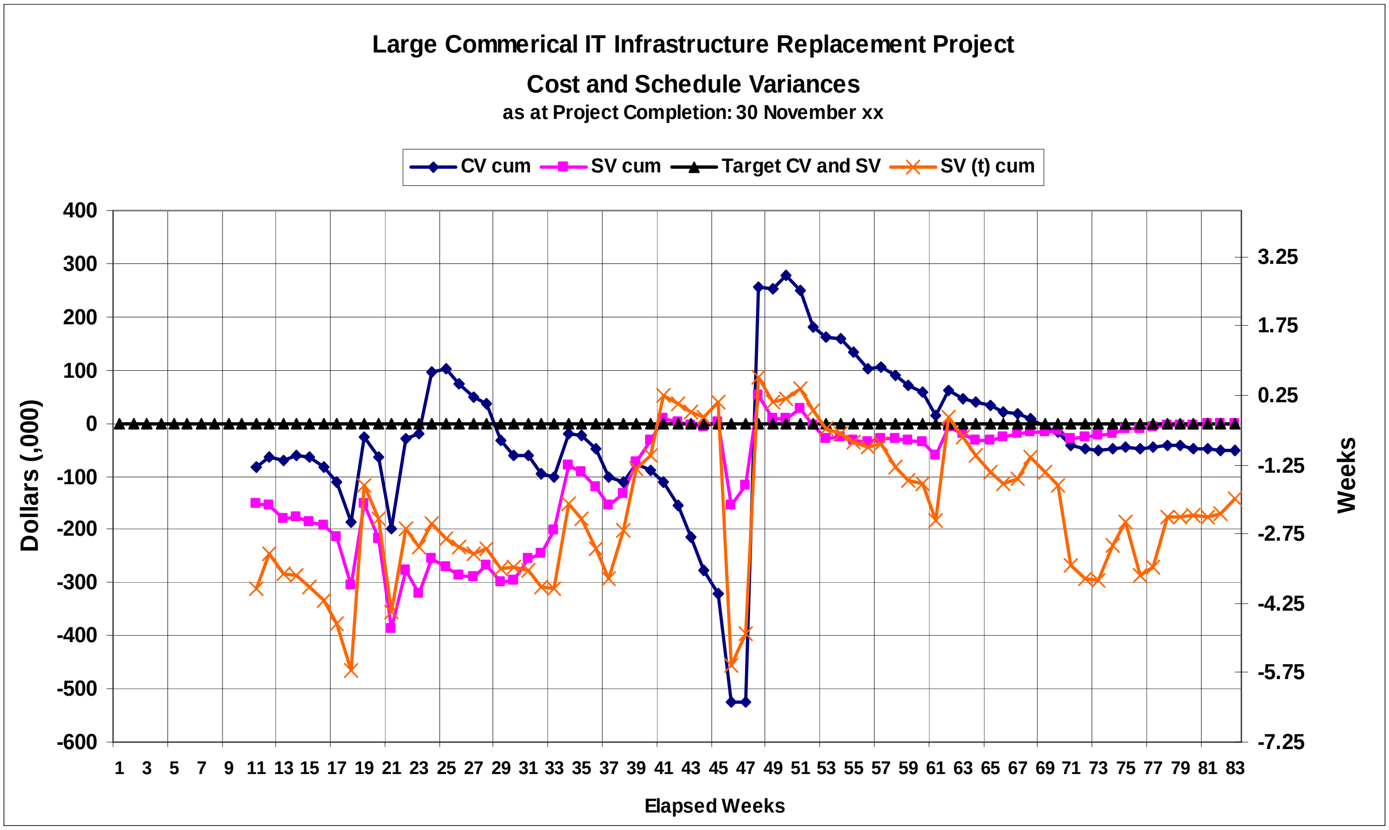


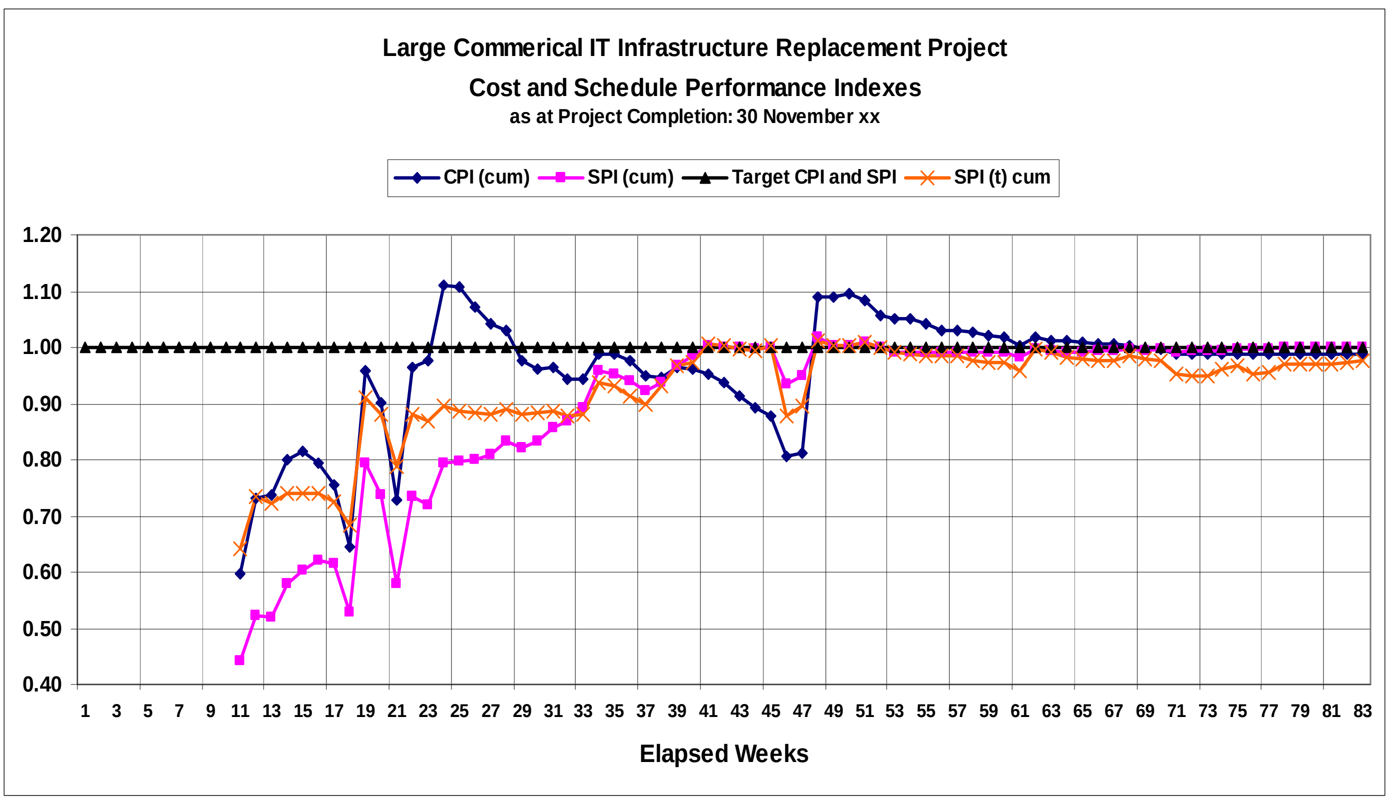
Project 4: Early Finish Software Development Project





Project 5: Late Finish Large Commercial IT Infrastructure Replacement Project (re-baselined in Week 48)





Project 6: Late Finish Commercial IT Software Interface Development sub-project (part of project 5)