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Prediction of project outcome The application of statistical methods to earned value management and earned schedule performance indexes

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Abstract

Earned value management (EVM) has provided methods for predicting the final cost for projects. In large part, these methods have not been improved upon since their beginnings and, with one exception, remain unsubstantiated as to accuracy. At the present time, EVM application guidance does not support prediction of final duration for the schedule component of projects.

The objective of this research is to improve the capability of project managers for making informed decisions by providing a reliable forecasting method of the final cost and duration. The method put forth and its evaluation make use of a well established project management method, a recent technique for analyzing schedule performance, and the mathematics of statistics to achieve its purpose – EVM, earned schedule (ES) and statistical prediction and testing methods.

The calculation method proposed was studied using data from 12 projects. The results for both final cost and duration are shown to be sufficiently reliable for general application of the forecasting method. The use of the method is encouraged; it may be applied irrespective of the type of work or cost and duration magnitude of the project.

Keywords: Project management; Earned value management; Earned schedule; Prediction; Forecasting; Statistics

1. Background and overview

Earned value management (EVM) is a method of project management, which facilitates project control and provides support in forecasting final cost. While literature shows that EVM outcome prediction for cost is reasonably reliable for very large United States Department of Defense (USDoD) projects [1–5], it is important for all managers, including those managing low cost, short duration projects, to have reliable forecasting tools. Likewise, having an independent estimation tool for predicting project duration is equally valuable. Significant improvement is needed to expand the utility of cost prediction and, develop the very much desired capability to reliably forecast schedule duration at completion.

Thus, the objective of this paper is to improve the forecasting of project outcomes. With improvement, project managers will have better information for their actions.

The method put forth and its evaluation make use of a well established project management method, a recent technique for analyzing schedule performance, and the mathematics of statistics to achieve its purpose – EVM [6], earned schedule (ES) [7,8], statistical prediction [9] and testing methods [10].

The paper's structure includes a short introduction to EVM, then a brief explanation of ES followed by a description of the statistical methods employed. The

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project data used is characterized; subsequently, the research study is described, including the presentation of results and analysis.

2. Review of earned value management and research

An understanding of EVM is assumed in this paper. For convenience, the terminology EVM uses to portray project status and forecast final cost follows:

PV	planned value
AC	actual cost
EV	earned value
CV	cost variance (CV = EV − AC)
SV	schedule variance (SV = EV − PV)
CPI	cost performance index (CPI = EV/AC)
SPI	schedule performance index (SPI = EV/PV)
BAC	budget at completion (the planned cost of the project)
PMB	performance measurement baseline (the cumulative PV over time)
IEAC	independent estimate at completion (the forecasted final cost)

From the 1990 cancellation of the USDoD project for development of the Navy stealth aircraft, the A-12 Avenger, interest heightened for having a better understanding of EVM. From this interest, several studies were performed regarding the CPI and IEAC, and to a much lesser degree the SPI. Several findings came from these efforts [1–5], summarized as follows:

(1) The result from IEAC = BAC/CPI is a reasonable running estimate of the low value for final cost.
(2) The cumulative value of CPI stabilizes by the time the project is 20% complete. Stability is defined to mean that the final CPI does not vary by more than 0.10 from the value at 20% complete ($CPI_{20\%}$).
(3) The range for final cost is obtainable from finding 2: $IEAC = BAC/(CPI_{20\%} \pm 0.10)$.
(4) The value of CPI tends only to worsen from the point of stability until project completion.

The four research findings above were obtained exclusively from USDoD datasets. They have come to be regarded as being generally applicable [11]. That is, these findings are considered equally applicable to all types of work – construction, defense new system development, and software development, spanning from the extremely large multibillion dollar defense efforts lasting more than a decade to small information technology projects, for instance, of $100,000 requiring less than one year for completion. However, managers of small projects report that they very seldom observe the finding for CPI stability. ited ability to produce reliable forecasts of project cost outcome.

From a recent publication [12] it is shown that findings 2 and 3, which require stability of CPI at 20% complete, are likely applicable only for extremely large projects of long duration. Thus, it is questionable whether managers of small projects can expect reliable decision information from their use.

3. Introduction to earned schedule

EVM and its indicators of project performance are well known and to some degree their behavior is understood. As previously discussed, there have been several studies of the behavior of CPI and IEAC. However, SPI is a different matter. The EVM schedule indicators, SPI and SV, are not so well studied because they are broadly recognized for failing when projects continue execution past the planned end date. For late finish projects, SPI converges and concludes at the value 1.00 while SV behaves similarly, converging and concluding at 0.00. With this flaw schedule prediction cannot be performed reliably using SPI.

A recent extension to EVM has emerged which provides reliable, useful schedule performance information. The extension is earned schedule (ES) [7]. In brief, the method yields time-based indicators, unlike the cost-based indicators for schedule performance offered by EVM.

Fig. 1 is an illustration for understanding the concept. The ES measure identifies when the amount of EV accrued should have occurred. As depicted by the diagram, this is the point on the PMB where PV equals the EV accrued. 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 earned schedule (ES).

While ES could be determined graphically as described previously, the concept becomes much more useful when facilitated as a calculation. ES has two components in its calculation. One is the number of time increments of the PMB for which EV is greater than or equal to PV; this component is termed "C". The second component is "I". The calculation of I is a linear interpolation. From Fig. 1, it is observed that the intersection of the PMB for the condition PV = EV describes a time that does not align exactly on a time increment beginning; it is in-between. The interpolation value is computed using the equation, $I = (EV - PV_C)/(PV_{C+1} - PV_C)$, where C is as described previously. Therefore I is the amount of ES accrued within the increment of the PMB from PV at C to PV at $C + 1$. Thus the schedule duration earned, in equation form, is $ES = C + I$.

As further explanation of the linear interpolation portion of ES, it should be made clear that the I component of ES involves only the final time increment of the calculation. The curve of the PMB is not a defined mathematical function; it is created from the cumulative value of PV

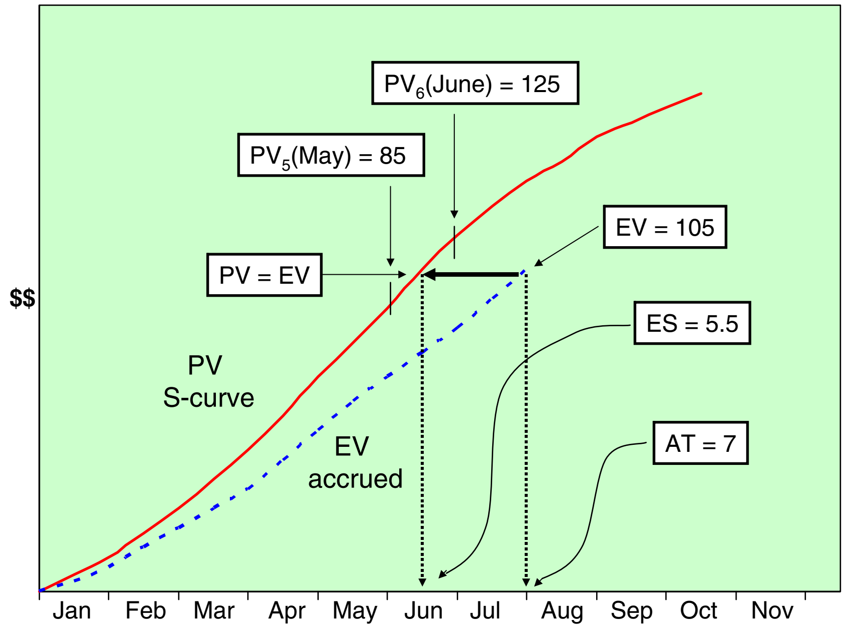

Fig. 1. Earned schedule concept.

portion of the final increment to claim as complete. One final note, as the count C becomes larger, the interpolated portion becomes less proportionately and, consequently, the error in the ES value due to the linear approximation of I becomes insignificant. For example, the maximum error ES may have with 3 months of EV data is 3%; after 10 months, the error is <1%.

With ES determined, time-based indicators can be formed. It is now possible to compare where the project is time-wise 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 readily formulated from the two measures, ES and AT. Schedule variance becomes $SV(t) = ES - AT$, and schedule performance index is $SPI(t) = ES/AT$.

To summarize, the terms and indicator equations developed for ES are as follows:

AT	actual time (the number of time increments corresponding to EV)
ES	earned schedule ($ES = C + I$)
C	number of whole time increments of PMB for condition $EV \geqslant PV$
I	portion of PMB increment earned ($I = (EV - PV_C)/(PV_{C+1} - PV_C)$)
SV(t)	schedule variance (time) ($SV(t) = ES - AT$)
SPI(t)	schedule performance index (time) ($SPI(t) = ES/AT$)

Using Fig. 1, an example of the ES calculations can be illustrated. As seen from the figure, all of the PV through duration of the completed portion of the planned schedule is in excess of 5 months; thus $C = 5$. The EV accrued appears at the end of July, making AT equal to 7 months. The method of calculation to determine the portion of June to credit to ES is the linear interpolation described earlier. 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.

From the values shown in Fig. 1, I can be determined: PV at the end of May is equal to 85, PV at the end of June is 125, and EV is 105. The numerator of I is equal to $EV - PV_5(May) = 105 - 85 = 20$. The denominator, $PV_6(June) - PV_5(May)$, is equal to $125 - 85 = 40$. Thus, the fraction of the June portion of the PMB contributing to the value of ES is 20 divided by 40 or 0.5. Therefore for our example, $ES = 5 + 0.5 = 5.5$. With $AT = 7$, the indicators can be determined: $SV(t) = 5.5 - 7 = -1.5$ months, $SPI(t) = 5.5/7 = 0.79$.

Earlier, it was discussed that final cost may be forecast from the formula, $IEAC = BAC/CPI$. In an analogous manner final duration may be predicted from $IEAC(t) = PD/SPI(t)$, where PD is the planned duration for the project and IEAC(t) is the independent estimate at completion (time). From recent research, it has been shown that ES, on average, is a better predictor of final duration than other commonly used EVM-based schedule forecasting methods [13,14].

4. Forecasting with statistics

Having reliable indicators for both cost and schedule, tion. The mathematics of statistics has the facility to further refine the forecasts of cost and duration by expanding them to include the forecast of high and low outcomes. By having the forecast for the high and low bounds for the cost and schedule outcomes, project managers have significantly improved information with which to make decisions affecting project success [15].

These aforementioned bounds are known as *confidence limits* [9]. The statistical equation for the confidence limits (CL) is

$$\mathrm{CL} = \mathrm{Average} \pm Z * \sigma/\sqrt{n}$$

where Z is the normal distribution value representing the level of confidence, σ is the standard deviation (the variation in the periodic values), n is the number of observations.

Confidence limits are frequently calculated at 90% or 95% levels. For the normal distribution, $Z = 1.6449$ and 1.9600 at 90% and 95%, respectively [9]. It is to be noted that as the percentage increases, so does the value of Z. Thus, the confidence limits for 95% are further from the average than are those for 90%. When the number of observations is less than 30, it is recommended to use the value of t from the t distribution instead of Z.

As observed from the above formula for CL, the calculation of confidence limits requires an average or mean value and a standard deviation [9]. The logarithm of the cumulative index approximates the mean value needed [16]. The estimates for the standard deviations are obtained by using the logarithms of the periodic values of the indexes, $\mathrm{CPI_p}$ and $\mathrm{SPI}(t)_\mathrm{p}$. The estimate of the standard deviation is computed using the following equation:

$$\sigma = \sqrt{(}\sum(\ln\ \text{periodic index (i)} - \ln\ \text{cumulative index})^2/(n-1))$$

where the sum ($\sum$) is over all of the periodic observations, denoted by (i), from the beginning of the project through the present.

As further explanation of the preceding discussion, logarithms are used because they have been shown to cause the periodic values of the indexes to approximate a normal distribution [17].

Statistical methods assume the population under examination is infinite. However, projects are finite; they have a start and an end. For finite populations, the statistical calculations are adjusted. As the project moves toward completion the adjustment causes the upper and lower confidence limits to approach each other, concluding at the same value, the mean. The adjustment factor is derived from the statistics formula $\sqrt{((N-n)/(N-1))}$, where for our application N is the total number of observations and n is the number of observations in the sample of N [9]. Making the appropriate substitutions, the

$$\mathrm{AFc} = \sqrt{(}(\mathrm{BAC}-\mathrm{EV})/(\mathrm{BAC}-(\mathrm{EV}/n)))$$
$$\mathrm{AFs} = \sqrt{(}(\mathrm{PD}-\mathrm{ES})/(\mathrm{PD}-(\mathrm{ES}/n)))$$

Combining the elements from the preceding discussion yields the general equation for the confidence limits used for the study

$$\mathrm{CL} = \ln\ \mathrm{index(cum)} \pm Z * \sigma/\sqrt{n} * \mathrm{AF}$$

The results from the CL computations are logarithms of the cumulative indexes. Thus, conversion is required, accomplished by raising the natural number "*e*" (2.718...) to the power CL. In turn, the extremes of the indexes are used to calculate the estimates of the bounds for final cost and duration. For example, the forecast of the high bound for cost, $\mathrm{IEAC_H}$, is calculated using the low CL value associated with cost performance, $\mathrm{CL_c}(-)$, as follows:

$$\mathrm{IEAC_H} = \mathrm{BAC}/\mathrm{EXP}(\mathrm{CL_c}(-))$$

where EXP indicates the mathematical operation of raising the number e to the power $\mathrm{CL_c}(-)$.

Similarly, the duration bounds forecast for the schedule are calculated using the confidence limits determined from the cumulative and periodic values of $\mathrm{SPI}(t)$: $\mathrm{IEAC}(t) = \mathrm{PD}/\mathrm{EXP}(\mathrm{CL_s})$. The subscript "s" of $\mathrm{CL_s}$ denotes that the confidence limit is derived from schedule performance.

5. Methodology

The objective of the study is to show that the values for the high and low bounds for both cost and schedule obtained from the statistical computations provide reliably good project management information. For each set of project data used in the study, all of the computations are iterated thereby creating revised upper and lower bounds for each newly added periodic observation. These upper and lower bounds inclusive from beginning to conclusion for each project are then tested using statistical hypothesis testing, specifically the Sign Test at 0.05 level of significance [10]. The Sign Test can be formulated to evaluate the tendency of one sample to be equal to, greater than or less than a second sample. For our use, the Sign Test is applied to separately test for the greater than and less than conditions:

(1) H_1 (cost-high bound): Final cost is less than $\mathrm{IEAC_H}$.
(2) H_2 (cost-low bound): Final cost is greater than $\mathrm{IEAC_L}$.
(3) H_3 (Schedule-high bound): Final duration is less than $\mathrm{IEAC}(t)_\mathrm{H}$.
(4) H_4 (Schedule-low bound): Final duration is greater than $\mathrm{IEAC}(t)_\mathrm{L}$.

The result from the hypothesis testing for each project when it is not [10]. The results are tabulated for the high and low bounds for each project and are subsequently used to compute the probability of obtaining reliable results. The probability for having reliable results (Ha) is computed using the binomial distribution.

The method described is applied to the high and low bounds computed for various levels of statistical confidence and subsets of the data. The statistical confidence levels used in the study are 90%, 95% and 98%. Three datasets are analyzed with the inclusion of project data beginning at 10%, 30% and 60% complete of final duration. By combining confidence level and datasets, a project cost and duration prediction method is sought for general application.

6. Description of the data

Twelve projects are used in the study, totaling 497 months of EVM data. All monthly budget and cost data was obtained from a single management information system, under the supervision of the same financial control manager throughout. The projects are considered low-risk with little development work involved. The output from the projects is high technology products.

Planned cost and schedule information is tabulated in Table 1. Also shown are the final cost and schedule performance index values. From the data table it is seen that planned cost ranges (in US dollars) from $291,000 to $6,077,000 with planned durations ranging from 17 to 50 months. Also observed from the index values, CPI ranges from 0.481 to 1.051 and SPI(t) from 0.739 to 1.000. With one exception, project 5, SPI(t) values are better than those for CPI. This implies that achieving schedule commitments was more important for these projects than the associated cost goals. Even so, it is observed that in only two instances, projects 5 and 12, was the planned duration achieved.

Initial comparisons, between projects, indicate a large amount of variation in the cumulative indicators and the standard deviations for both cost and schedule. In Table 1 is a compilation of the observations. The subscript "c" used in Table 1 indicates cumulative, whereas the subscript "p" denotes periodic indexes. The indicators and standard deviations were computed using all of the data for each project.

The variations of the cost and schedule indexes and standard deviations (σ) are fairly comparable with schedule being somewhat larger. However, the range values exceeded our expectation. The averages of the range, i.e., high minus low values shown in Table 1, are indicative of the large variation. Distinguishing the range averages by "<variable>", we computed the following: $\langle CPI_c \rangle = 0.306$, $\langle \sigma(\text{cost}) \rangle = 0.594$, $\langle SPI(t)_c \rangle = 0.468$, $\langle \sigma(\text{schedule}) \rangle = 0.663$. These values for the standard deviations are larger than observations from previous study [12].

Likewise, the amount of change for the index values of several projects over the last 20% of the duration was unexpected. Of the 12 projects four had changes in their CPI values of approximately 0.10 between 80% and 100% duration while seven had changes exceeding 0.05. This observation is not supportive of the research finding discussed earlier; i.e., final CPI will not vary by more than 0.10 from the CPI value at 20% complete.

7. Results analysis

An example of the prediction of upper and lower bounds using the statistics computation methodology is shown in Fig. 2. The calculations were made using the 90% confidence level. A key observation is the difference between the upper and lower bound becoming smaller and smaller as the percent complete increases, eventually becoming the same value at project completion. The graph portraying cost prediction indicates that cumulative CPI is very stable between 50% and 100% complete because of the stability observed for IEAC. The schedule graph shows that SPI(t) is consistently worsening thereby causing IEAC(t) to increase throughout the execution of the project. The high bound, IEAC$(t)_H$, prediction beginning near

Table 1
Project data and variation

Project	BAC (×$000)	PD (months)	CPI_c (final)	$SPI(t)_c$ (final)	CPI_c		$\sigma(\ln CPI_p)$		$SPI(t)_c$		$\sigma(\ln SPI(t)_p)$	
					High	Low	High	Low	High	Low	High	Low
#1	898	21	0.741	0.875	0.875	0.608	1.093	0.448	1.950	0.875	0.539	0.204
#2	605	32	0.695	0.842	0.887	0.566	0.713	0.028	1.139	0.710	0.653	0.035
#3	322	36	0.481	0.837	0.841	0.472	0.704	0.055	0.899	0.326	1.421	0.124
#4	613	43	0.793	0.915	0.986	0.775	0.683	0.205	1.000	0.583	1.009	0.287
#5	291	24	1.051	1.000	1.354	1.041	0.525	0.132	1.082	0.875	0.347	0.201
#6	1525	50	0.625	0.847	1.000	0.566	0.835	0.147	0.972	0.667	0.759	0.247
#7	585	46	0.763	0.852	1.042	0.667	0.683	0.321	1.018	0.727	0.668	0.283
#8	1026	29	0.877	0.967	0.914	0.714	0.253	0.087	1.054	0.761	0.622	0.000
#9	2223	45	0.746	0.818	1.043	0.610	1.410	0.036	1.000	0.650	1.297	0.000
#10	6077	44	0.870	0.880	1.053	0.870	0.452	0.009	1.657	0.592	1.033	0.385

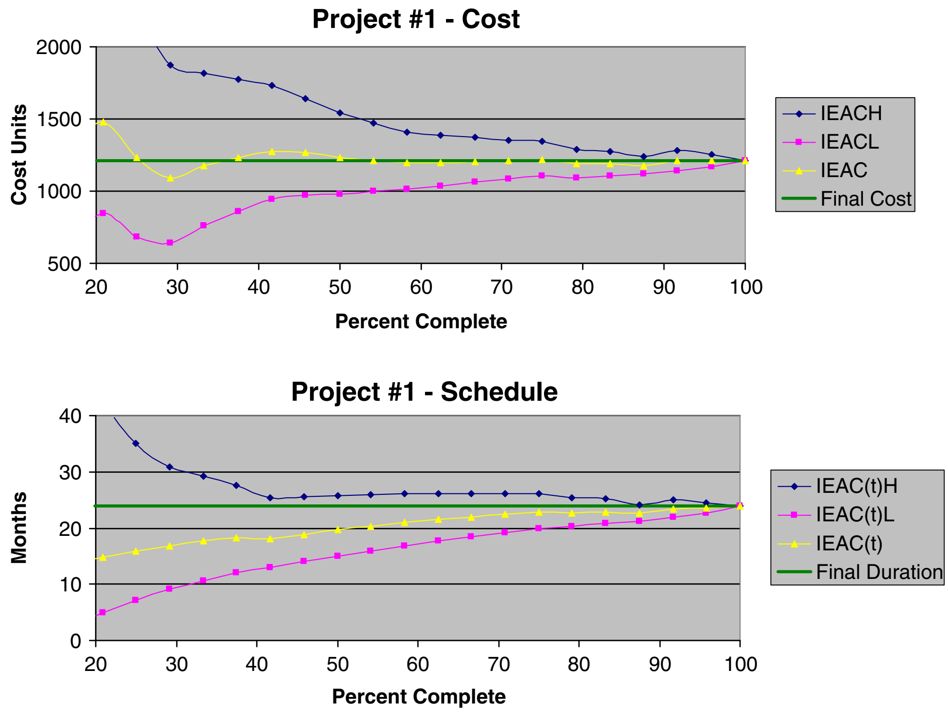

Fig. 2. Cost and schedule prediction.

30% complete through to the end proved to be very close to the eventual schedule duration outcome.

Table 2 below illustrates one of the five scenarios analyzed. For this scenario, the upper and lower bounds were computed at 98% confidence level. The data set tested included all data points from 10% duration complete until finish. The entries of Ho and Ha in the figure represent the null and alternate hypothesis, respectively, and are the results of the Sign Test of the four hypotheses specified earlier. Recall the testing result of Ha, indicates that the test statistic is within the critical region of 0.05 significance [10]; i.e., the upper bound is consistently higher than the final value, or the lower bound is consistently lower. The test statistic values are recorded in the table beneath the null or alternate hypothesis determination. The conclusion from the example is the computation yields reliable forecasts throughout the project for the high and low values of both cost and duration when applied at 98% confidence using data beginning at 10% complete.

A compilation of test results for all of the scenarios is shown in Table 3. The five scenarios tested were: 90% confidence level, applied to data beginning with 10%, 30% and 60% complete; 95% and 98% level, using data beginning from 10% complete. These values were chosen, so that results can be compared to answer the following questions:

(1) How does confidence level affect reliability of prediction?
(2) How does inclusion of data beginning at various values of project percent complete affect reliability of prediction?

Table 2
Hypothesis test results @ 98% confidence ⩾10% complete

Bounds	Project number												Probability
	1	2	3	4	5	6	7	8	9	10	11	12	
Cost high	Ha 0.000	Ha 0.000	Ho 0.500	Ha 0.044	Ho 0.500	Ha 0.000	Ho 0.844	Ha 0.000	Ha 0.000	Ho 0.116	Ha 0.000	Ha 0.000	0.927
Cost low	Ha 0.000	Ho 0.804	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	1.000
Schedule high	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.000	Ha 0.003	Ha 0.000	Ha 0.000	Ho 0.132	Ha 0.000	1.000
Schedule low	Ha [illegible]	Ha [illegible]	Ho [illegible]	Ha [illegible]	Ha [illegible]	Ha [illegible]	Ha [illegible]	Ha [illegible]	Ha [illegible]	Ha [illegible]	Ha [illegible]	Ho [illegible]	0.997

Table 3
Prediction probability

Bounds		90% Confidence			95% Confidence	98% Confidence
		⩾10% Complete	⩾30% Complete	⩾60% Complete	⩾10% Complete	⩾10% Complete
Cost	High	0.613	0.613	0.927	0.613	0.927
	Low	1.000	1.000	0.981	1.000	1.000
Schedule	High	1.000	1.000	1.000	1.000	1.000
	Low	0.997	0.981	0.997	0.997	0.997

The results portray an expectation. As confidence level increases, the probability of obtaining the hypothesis test result, Ha, increases. This assertion is readily understood upon recalling that the high bound increases and the low bound decreases, i.e., the range between high and low widens with increasing confidence level percentage. Likewise, as the data is increasingly restricted to the observations nearing the conclusion of the project the greater the probability for having Ha as the test outcome. This result follows from the cumulative index becoming increasingly stable as the project approaches completion. We see these expectations realized in the percent complete progression within the 90% confidence level scenario and similarly in the progression of increasing confidence level percentage.

From the results displayed in Table 3, it appears that the general approach for obtaining the most reliable estimates of the high and low bounds is by using 98% confidence level. This approach certainly is the safest. The 90% and 95% confidence level estimates have greater risk of providing faulty results as explained in the previous paragraph. However, there is a trade-off: the larger the confidence percentage, the greater is the likelihood that the bounds are overestimated.

A further observation from Table 3 is that reliable estimates are made when 90% confidence was applied to the portion of data beginning at 60% complete (90/60). As a matter of interest, previous work determined 60% complete to be the generalized stability point for the cost index from our project data [18]. This connection to the stability point adds credence to the assertion made earlier that as the index becomes more stable, a lower percentage confidence level may be applied with the expectation of obtaining reliable forecasts for the bounds.

From the 90/60 testing result and other factors, we believe that using 90% confidence is reasonable under most circumstances. For this set of data, greater variation was observed in cumulative indexes and standard deviation than was expected. Also fairly large variation in the cumulative performance indexes was seen for several projects after 80% complete; whereas, normally small variation is observed when projects are nearing completion.

Lastly, from the comparison of final values of CPI and SPI(t) earlier in the paper, we deduced that achieving the schedule commitment appeared to have priority. The focus on controlling schedule performance is thought to have caused costs to be skewed higher. The tendency toward those for the other bounds. If not all of these anomalies had been present in the data, it is conjectured that 90% confidence would provide reliable upper and lower bounds.

8. Summary

For the 40 years of application of EVM the forecasting methods for final cost have been used with little change. Only in the last 15 has there been research as to the validity of the cost prediction results. The research performed on large USA defense projects generated four findings which are commonly generalized as being applicable to all projects. Recently it has been shown that some of these research results may be applicable only to extremely large projects of very long duration.

Over the history of EVM a few unproven methods have been used for forecasting schedule duration. An emerging practice, earned schedule, employing time-based schedule performance indicators has provided facility to predict schedule results. From recent research the ES method has been shown to be better, on average, than other EVM-based approaches to schedule prediction.

Nearly 500 months of data from 12 projects were used in the study. The general findings from the analysis of the project data were higher variation than expected and consistently better performance for schedule than cost.

This paper provides the results for predicting project outcome from the application of statistical methods to CPI from EVM and SPI(t) from ES. The statistical testing of predicted upper and lower bounds for project cost and schedule duration indicates generally good performance from the proposed method regardless of confidence level chosen. It was seen that by increasing confidence level the probability increases for having reliable bounds. Using 98% confidence provided very good forecasting beginning as early as at 10% complete. At 90% confidence, reliable prediction of high and low bounds was seen beginning at 60% complete. Due to the unique characteristics of the data, it is postulated that 90% confidence is appropriate for most circumstances.

9. Concluding remarks

Although this study used a comparatively small data sample, characterized as primarily low to moderate cost, with short to moderately long duration projects, we believe restricted; they may be used for all types and sizes of projects, spanning from low cost-short duration to high cost-long duration and from information technology to defense. It is our opinion the methods discussed in the paper will produce very useful information thereby providing a valuable project management tool, having the potential to enhance project control and increase the number of successful project deliveries.

Some practitioners of EVM hold a belief that project duration forecasting can be made only through the analysis of the network schedule. They maintain the understanding and analysis of task precedence and float within the schedule cannot be accounted for by an indicator. Detailed schedule analysis is a burdensome activity and if performed often can have disrupting effects on the project team. Earned Schedule offers calculation methods yielding reliable results, which greatly simplify final duration and completion date forecasting. A previously published study comparing ES to Critical Path prediction supports this assertion [19]. Likewise, this paper indicates project duration can be forecast reliably using the ES predictors. In fact, the results of this paper indicate an overall better prediction for schedule than for cost.

Future research of the proposed method is encouraged. To promote the trialing and uptake of the techniques described in this paper a statistical prediction calculator has been placed into the public domain at http://www.earnedschedule.com/Calculator.shtml.

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