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A Comparison of different Cost forecasting methods using Earned Value Metrics

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Abstract
Efficient decision making mandates the accuracy of forecasted estimations of a Project's final value termed as Cost Estimate at Completion (CEAC) in Earned Value Management. The greatest benefit gained by use of EVM is its ability to predict project outcome and potentially prevent project failure. To develop project management proficiency, organizations need to look at the critical elements of EVM as pragmatic stepping stones to prioritizing which project management processes are most important for successful delivery. In this paper the most commonly used predictive tools based on the performance indices, which are compared with a nonlinear regression based CEAC. Gompertz growth model is adopted, the input data is modified with cost variance and schedule variance. The output is modified with earned schedule which helps in predicting CEAC more accurately. Five data sets are used in the comparative study of CEAC methods. The model based on nonlinear regression is found to be the most accurate and precise method in the early stages of the Project as compared to other Index based methods.

Keywords: *EVM, ES, Nonlinear Regression Analysis, Performance Management.*

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I. INTRODUCTION

Project management demands the proper management of people and the knowledge about the various techniques, methods, processes etc. involved in a project. Balancing of the triple constraints of time, money and quality results in the satisfactory project output. The performance reporting is a part of the project monitoring and control process. The earned value method is useful for reporting the status of the project as well as to predict the future performance based upon the past performance. For almost thirty years, earned value was a part of Cost/ Schedule Control Systems Criteria (C/SCSC). Earned Value Management system is emerged out of these ambiguities and showed way for better performance management. The Performance Measurement Baseline is highly important to earned value management because it provides the baseline plan to measure the project's performance. It is the sum of the project's planned cost over time and establishes the scope, schedule and budget for a project. A baseline should accurately represent the only authorized work on the contract. It includes a realistic network schedule baseline, and a realistic time phased spread of budget to the baseline schedule.

Performance is measured by determining the budgeted cost of the work performed (i.e. earned value) and comparing it to the actual cost of the work performed (i.e. actual cost). Progress is measured by comparing the earned value to the planned value." (PMI 2004, p. 359). Earned Value Management has got any modifications as time proceeds. This paper modifies the EVM using nonlinear regression method which incorporates Cost Variance and Earned Schedule

1.1 Earned schedule

The earned value management method is at tremendous aid in project planning, tracking and decision making. Also the reporting methods of EVM serve as a good tool for communicating with the management, But the new users of EVM find it difficult to understand the schedule performance in units of cost; also as the project approaches its completion (which was behind schedule), the schedule variance become zero and the schedule performance index becomes unity regardless of the real situation of late finish of the project. This is a major drawback of EVM and also EVM fail to provide good information, normally over the final third of the project: they absolutely break down if the project is executing past its planned completion date. To overcome these difficulties of EVM, a new improved method is introduced, which is called the Earned Schedule Method.

1.1.1 Schedule Performance in EVM The Problem

For explaining the problem of earned value schedule performance indicators, we use the graphs from the paper "Schedule is different". The graphs of variances and indices are given in Figure 1. From the graphs it is clear that the cost variance as well as the cost performance index establish a trend with some variation. But

checking the schedule indicators i.e., schedule variance and schedule performance index, appear to establish a trend, but eventually begin moving toward their end result, zero variance and an index value equal to unity. This quirky behaviour of SV and SPI occurs without fail for every project finishing late, no matter how late (Lipke, 2003). This behaviour of the schedule indicators cannot be presented to other stakeholders. The problem arises because the late delivery of product cannot be identified.

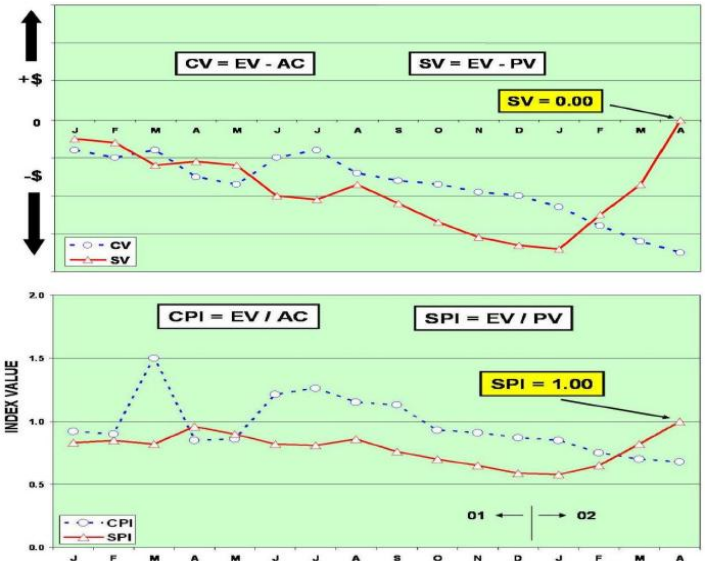

Figure 1. Failure of SV and SPI at project completion (Lipke 2003)

1.1.2 Why Schedule Indicators fail?

We have the cost and schedule indicator formulas from EVM as follows:

CV=EV-AC
CPI = EV/AC
SP1= EV/PV
SV = EV-PV

In EVM the cost indicators are referenced to actual costs (AC), whereas the schedule indicators are referenced to the baseline performance (PV). It is this reference to PV, which causes the problem for schedule indicators. The end point of PV is the planned cost for the project, Budget at Completion (BAC). The end point of the earned value (EV) is, likewise BAC. Thus as the earned value approaches project completion, it converges to the planned cost. In case of a late project. PV equals BAC, while EV incrementally achieves the value. That is why SV converges to 0.0 and SPI concludes at 1.0 at project completion.

1.1.3 Overcoming the Problem by Introducing Earned Schedule

The idea of Earned Schedule is analogous to Earned Value. But in earned schedule, instead of using cost for measuring schedule performance, time is used. Earned schedule is determined by comparing the cumulative EV earned to the performance baseline, PV. The time associated with EV, i.e., Earned Schedule, is found from the PV S-curve. The significance of using the ES concept is that the associated schedule indicators behave appropriately throughout the entire period of project performance, (Lipke 2009).

Earned Schedule is found out as illustrated in the Figure 2. The cumulative value of ES is found by using EV 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 plus a fraction of it. The fractional amount is equal to the portion of EV extending into the incomplete time increment divided by the total BCWS planned for that same time period.

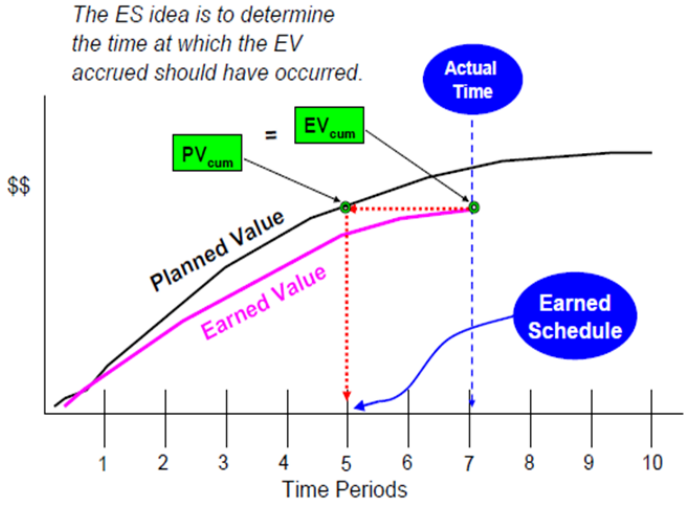

Figure 2. Earned Schedule Concept (Lipke 2009)

1.1.4 Earned Schedule Duration Forecasting

The extension to EVM, ES provides reliable, useful schedule performance management information. In brief, the method yields time-based indicators, unlike the cost-based indicators for schedule performance offered by EVM.

Figure 2.3 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).

1.1.5 Estimate at Completion (EAC)

Data on the cost and schedule progress of a major defense contract are prepared by the contractor and submitted to the government on a cost management report. The monthly report is considered reliable if the contractor has met certain government standards for cost and schedule performance measurement, termed "Cost/Schedule Control Systems Criteria" (C/SCSC). Today, most major defense contractors have management reporting systems that have been found to be C/SCSC-compliant, (Christensen 1993).

The cost management report typically lists performance data using the framework of a product-oriented work breakdown structure. Key data elements include the budgeted cost of work scheduled (BCWS), the budgeted cost of work performed (BCWP), and the actual cost of work performed (ACWP).

1.2 Data Analysis

The conventional CEAC methods and proposed CEAC methodology is demonstrated through five infrastructure projects. Five past projects were selected for the analysis of this project because they have all the necessary data readily available at ones disposal and one would know the endpoint of the project which helps significantly in understanding the method in which CEAC methods works on projects. These projects all have medium-sized budgets with an average BAC close to 3 Crore INR and planned duration varying from 9 to 20 months.

Table 1: List of Projects and their average performance indicators

Project	Planned Value		CPI	SPI
	Time (months)	Cost (Lakhs)		
Project A	18	231.28	0.844	0.957
Project B	20	480.00	0.888	0.960
Project C	9	287.50	0.912	0.857
Project D	9	360.73	1.040	0.913

Project E	10	90.60	0.970	1.060

For the comparison of the CEAC methods all the CEAC values of five projects by five methods are tabulated and shown in Table.

Table 2: Comparing CEAC Methods

PROJECTS	% Comp.	CEAC1	CEAC2	CEAC3	CEAC4	CEAC5
PROJECT 1 231.28	25%	241.880	304.592	317.982	249.114	253.057
	50%	248.780	268.293	283.333	250.759	258.742
	75%	255.820	261.678	278.510	264.659	273.353
PROJECT 2 480	25%	496.590	560.299	585.723	519.031	531.173
	50%	508.910	541.002	576.367	518.486	533.340
	75%	523.490	534.524	564.178	547.539	562.559
PROJECT 3 287.5	25%	293.600	311.361	360.077	273.622	319.355
	50%	298.400	309.067	376.071	296.495	318.894
	75%	310.700	320.455	388.219	304.297	325.278
PROJECT 4 360.738	25%	349.896	316.859	325.910	354.431	366.279
	50%	353.351	347.331	381.210	353.003	360.722
	75%	353.881	352.280	389.816	315.307	325.501
PROJECT 5 906	25%	911.000	932.805	866.570	882.398	871.272
	50%	932.000	945.457	869.441	944.142	934.471
	75%	941.000	943.795	897.674	955.885	947.709

Percentage error (PE) shows the effectiveness of each method in finding CEAC. The accuracy of the estimates of the equations is based on a comparison of percentage error (PE), which is termed the difference between the actual and estimated values of final cost expressed as a percentage; and on the mean absolute percentage error (MAPE) of the number of valid projects tested.

Table 3: Percentage Variance at Completion from Cost at Completion

PROJECT	Evaluation Stage	EAC1	EAC2	EAC3	EAC4	EAC5
PROJECT 1 231.28	Early	6.858	17.291	22.447	4.073	2.554
	Middle	4.201	3.313	9.104	3.439	0.365
	Late	1.490	0.766	7.247	1.914	5.261
PROJECT 2 480	Early	6.189	5.847	10.649	1.949	0.344
	Middle	3.861	2.201	8.882	2.052	0.754
	Late	1.107	0.977	6.579	3.436	6.274
PROJECT 3 287.5	Early	9.578	4.108	10.895	15.731	1.646
	Middle	8.100	4.814	15.821	8.686	1.788
	Late	4.312	1.308	19.562	6.284	0.178
PROJECT 4 360.738	Early	0.148	9.308	6.717	1.446	4.837
	Middle	1.137	0.586	9.111	1.037	3.247
	Late	1.289	0.830	11.574	9.752	6.834
PROJECT 5 906	Early	4.307	2.016	8.974	7.311	8.480
	Middle	2.101	0.687	8.672	0.825	1.841
	Late	1.155	0.862	5.707	0.408	0.451

The percentage variance at completion is shown in shades of green and as the intensity of shade increases the variance increases from the cost at completion. Table shows lighter shade for EAC2 and EAC5. Calculating CEAC using schedule cost index, i.e., EAC3 method is flawed as it shows greater deviation from the required value. EAC1 shows somewhat closer value but it depends on the project. EAC1 doesn't seems to be a standard method for forecasting. Hence EAC1 and EAC3 are found to be not a good predicting method for CEAC.

II. RESULT AND DISCUSSION

Time and cost overruns are the key challenges for the infrastructure industry. About 40% of the ongoing infrastructure projects are running behind schedule. As per project managers, most of the delays are due to extraneous reasons that can be avoided by adhering to appropriate risk management, time management and change management processes. Proper performance analysis enables project managers to execute and review their projects in a more structured manner. The status of the 564 infrastructure projects in India. Almost half of them are delayed projects and one-third of it has not fixed the date of commissioning. Among them only 1% of the projects are ahead of schedule.

The comparative study of the CEAC methods shows that there is no particular method to find CEAC which stands as the best method. Even though the method introduced by modifying nonlinear regression shows to be a good predictor for projects which has CPI and SPI less than unity. The percentage error for projects with cost underrun and running ahead of schedule shows more error in regression based method. But for the projects having delay and cost overrun the regression based method shows the best results. The percentage error for the projects is shown in Table 4 and the light shaded cells showing least error. It is clear from the table that the EAC5 is the best method. The accuracy of the method is tested by MAPE and the precision of the method is checked by Standard deviation.

Table 4: Percentage Variance at Completion from Cost at Completion

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	Middle	8.100	4.814	15.821	8.686	1.788
	Late	4.312	1.308	19.562	6.284	0.178

The cumulative value of CPI, which gets stabilized as the project progresses. It ensures for more stable values of CEAC by the end of a project. For a project in its early life, when few EVM data are at hand, this technique is unreliable as it makes extrapolations from few time points for the rest of the project: this is risky and provides inaccurate estimates. But when the project attains some maturity the stabilized CPI with more past performance to support its forecasting it gives more reliable data for the late stage cost forecast. In most projects regardless of their nature, budget, and duration, estimates by a traditional approach stabilize by the second half of the project life or at late stage. Previous studies showed that the PI values (CPI and SPI(t)) converged to their respective final values as the project gets closer to completion.

Considering schedule progress as a factor of future cost improves both accuracy and precision of the developed model. EAC4 method doesn't include the earned schedule factor and the cost forecasted by this method is more erroneous than EAC5 which incorporates the earned schedule in CEAC calculation. EVM is a system that integrates project cost, schedule, and scope. In this regard, schedule is known as a factor of project cost performance. Delay in work progress has its influence on cost behavior. If the project is ahead of schedule it follows the estimated planned value so there won't be any extra cost due to delay rather it sticks to the planned

data. The majority of projects experience impact of schedule progress on their final cost. Therefore, EAC5 methodology makes explicit use of ES concepts in calculation of CEAC. This practical contribution of the ES method into the forecasting formula reflects schedule impact and, hence, provides more reliable CEAC.

III. CONCLUSION

Accurate CEAC forecasting helps the project managers to take required decisions on time which helps the project to complete on time and within budget. The methodology used in this paper holds well in the early and middle stages of a project which has cost overrun and are running late. In this paper the flaws in EVM is studied and a better performance analysis is suggested which uses the nonlinear regression analysis. The regression modified method uses the earned schedule suggested by Lipke which helps in forecasting CEAC for delay in projects. The input for the nonlinear regression analysis is modified by adding cost variance to the planned cost and adding earned schedule to the baseline. The output of the nonlinear regression analysis is then used to find the CEAC of the project and the commonly used equation is modified by earned schedule which gives better result.

The accuracy of the different cost forecasting methods are compared and EAC5 method gives the most accurate results. Also the EAC5 method is more precise compared to other methods with very less standard deviation. This paper suggests that the use of the regression modified method for the first half and CPI based index method in the second half of project gives more reliable information in cost forecasting. IB method produce inaccurate and unreliable data in the first half of the project duration but in second half the information available about the project is more and hence provide the best reliable CEAC forecast. The index based CEAC forecasting which started a few decades before was initially focused on large and complex projects but the method used in this paper is suitable for projects with any budget and duration.

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