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Research Paper

MONITORING OF CONSTRUCTION PROJECTS USING EVM AND ESM TOOLS

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Earned Value Management (EVM) is a powerful methodology that gives executives, project managers, and other stakeholders the ability to visualize project status throughout the project life cycle and consequently manage projects, programs, and portfolios more effectively. The Earned Schedule (ES) allows EVM metrics to be transformed to time or duration rnetrics to enhance the evaluation of project schedule performance and to forecast the duration needed to complete the project. When combined with schedule analysis, ES can enhance the project manager's understanding of project schedule forecasts and provide further insights for making better decisions about project schedule and related parameters. When should a manager take action to correct a project not performing well and what should he do if he decides to act on the performance of the project. A poor outcome is a certainty if the manager's decision and action are not appropriate. This paper discusses the questions, and the manager's considerations. It gives alerts to the project manager that where is he in the project, whether his project is behind schedule, ahead schedule or on schedule.

Keywords: Project Monitoring, Earned Value Management, Earned Schedule Management

INTRODUCTION

Project Managers worry about delivering a quality product, which performs as the customer expects. It's management's job to guide the project team to meet the negotiated commitment of technical performance, cost, and delivery date. It's tough to do. There are innumerable opportunities for negatively impacting the project throughout the entire period of performance. Several critical elements, such as personnel, facility, data, equipment, material, training, and subcontractors, have the potential to overcome the best of plans. It's not difficult for anyone with project management experience to recall many instances when each one of these elements caused additional cost and consumption of schedule.

To the best of the project team's ability, the risks associated with the critical elements are

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assessed. Subsequently, reserve in both cost and schedule is created to mitigate the risks foreseen. Often times however, to be competitive, project estimates and reserves are "squeezed," thereby creating a poor situation for the manager from the outset: an aggressive plan with inadequate risk mitigation resources.

The project manager can understand, very well, from the first day, the probability of success is not 90%. It's more likely to be 60%, at best. Therefore, a small amount of inefficiency caused by risk impacts will nearly consume the project's reserves.

The execution of the project plan with no variation is the most efficient manner of performance. When changes are made to compensate for critical element impacts, inefficiency is created and some of the reserves are consumed.

Therefore, to judiciously use the reserves, managers must have confidence that the change they induce will have benefit; i.e., the project will have a greater opportunity to complete within the cost and schedule commitment.

The remainder of the paper will create an approach for project analysis and decision-making. The approach will address:

- When a manager should act, and
- What action he should take.

A third aspect concerning the sufficiency of the action taken will also be discussed.

LITERATURE REVIEW

Project Management

Performance efficiency is measured by the Earned Value Management (EVM) cost performance index, CPI, and the Earned Schedule (ES) Schedule Performance Index, SPI (t). Project managers using EVM and ES in their management practice, thus, have a set of indicators, which provide information concerning the health of their project. If the project is performing at the planned efficiencies (CPI and SPI(t) equal to 1.0), the project is forecast to complete at the planned cost, and deliver its product on the expected delivery date. And, none of the planned reserves for cost or schedule will be consumed.

One method of forecasting whether a project will complete within its funding and negotiated delivery date is to compare the inverse indexes to ratios, which include the cost and schedule reserves. When the value of CPI is less than or equal to the cost ratio, the project manager has an expectation that the project will complete within the funding allocated. Correspondingly, if SPI(t) is less than the schedule ratio, the project is expected to finish by the negotiated completion date.

Of course, when the inverse indexes are greater than their respective ratios, the project manager knows his project is in trouble. The forecast indicates the plan will be exceeded, the reserves will be consumed, and more resources (time and funding) are needed. Understanding the project is failing, the project manager is inclined to take corrective action. And, certainly the pressures from upper management and the customer compel the project manager to show that corrective action is already in progress.

It may not be, but the project manager doesn't have anything in his tool kit to say he should do otherwise. Therefore, being proactive is his sole choice. Furthermore, the project manager knows that doing something, right or wrong, will buy time. Wishfully, within that time, a miracle happens and the project gets back on course. If good luck comes his way, the project is "righted," and our hero receives a bonus and maybe even a promotion.

More than likely, the outcome of a reactionary corrective action will not be effective. As mentioned previously, any change to the execution of the plan causes inefficiency. If the action taken is not the correct one, then management has inadvertently worsened the project performance and has not helped the situation. Subsequently, the manager, being proactive, takes another "shot in the dark," likely worsening the situation, once again. This process repeats until it becomes obvious to all concerned that the only way to deliver the product is to negotiate additional time and funding. The outcome of this negative spiral is the company and the project manager gain poor reputations. Additionally, if the product is extremely important and its sunk cost is significant with respect to the amount needed for completion, the agitated customer will likely agree to the added cost and delivery date extension. Under these circumstances, the company cannot expect repeat business or future recommendations from this customer.

Another common earned value approach is to manage using the Cost Variance (CV) percentage; i.e., CV divided by the EV. With this method the project manager takes corrective action upon breaching an arbitrary limit; e.g., plus or minus 10%. Generally, the results from the CV management method are as poor as described for CPI.

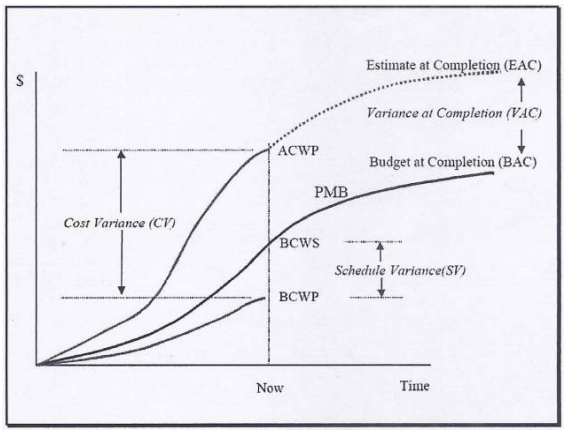
Certainly, there are successful projects, which have been managed using earned value indicators; we are not implying earned value management has no merit. Using earned value coupled with earned schedule as a project management method greatly increases the opportunity for success, but improvement is needed. Project performance data is readily available, but rarely is it used advantageously. This is the state of today's management practice.

Until the mid-19th century, the general method of design did not change a lot. Engineers used simple tools (such as pen, paper and ruler) to describe their buildings. However, with advances in mathematics and building materials, the process of design changed and improved rapidly.

ELEMENTS OF EARNED VALUE MANAGEMENT

EVM integrates three critical elements of project management: scope management, cost management, and time management. It requires the periodic monitoring of actual expenditures and the amount of work done (expressed in cost units). To determine cost performance, EVM compares how much we have spent to what we planned to have spent to do the work we have done. To determine time performance, it compares the amount of work done to the amount of work scheduled to be done. To make these comparisons, EVM calculates cost and schedule variances, along with performance indices for project performance management. Based on these

Figure 1: Earned Value Graph



results, it forecasts the date and cost of the project at completion and highlights the possible need for corrective action. EVM uses the following project parameters shown in the Figure 1 to evaluate project performance.

Planned Value (PV): This is the cumulative planned cost for the work planned to be done on the project up to a given point in time. It is the approved budget for completing the work planned so far, and as such it is the cost baseline for the project. It was previously called the Budgeted Cost of Work Scheduled (BCWS).

Budget at Completion (BAC): This is the total amount of money expected to be spent on the project, and as such it is the value that PV is planned to reach at completion.

Actual Cost (AC): This is the cumulative actual cost spent on the project so far, including all accrued cost on the work done. AC was previously called the Actual Cost of Work Performed (ACWP).

Earned Value (EV): This represents the cumulative amount of work done up to a point in time, expressed in cost units. It is expressed as the amount that was planned to have been spent on the work that has been completed up to this point. EV was previously called the Budgeted Cost of Work Performed (BCWP). To calculate the EV for a given element of work, the planned cost is multiplied by the percentage complete. The EV for the project is the sum of the EV for all the work elements.

BAC, PV, AC and EV are expressed in cost units. That may be in units of actual money, in any currency. Or it can be expressed in hours or days of work done. PV, AC and EV can be calculated for any element of work to determine progress on that element of work.

Project Performance Measurement

Cost performance on the project is determined by comparing EV to AC. AC represents what has actually been spent and accrued to do the work so far, and EV represents what was planned to be spent to do the work so far.

The difference shows whether the project is over spent or under spent. Schedule performance is determined by comparing the EV to the PV. PV shows the amount of work that was planned to have been done and EV represents the amount that has been done. By comparing the two, we can determine whether more or less work has been performed than should have been done, and whether the project is ahead of or behind schedule. We do these comparisons by calculating variances and the performance indices.

Variances

The following formulas are used to calculate the variances:

The CV is a measure of cost performance:

CV = EV – AC

Table 1: Showing Indicators and Predictors used in Earned Value Management

Indicators	Planned Value	PV		What is the estimated value of the work planned to be done?
	Earned Value	EV		What is the estimated value of the work actually accomplished?
	Actual Cost	AC		What is the actual cost incurred for the work accomplished?
	Cost Variance	CV	EV - AC	Negative means Over Budget
	Cost Performance Index	CPI	EV / AC	Contractor is getting only —Ps. Out of every 1 Rs. Spent into the project
	Schedule Variance	SV	EV - PV	Negative means project is behind schedule
	Schedule Performance Index	CPI	EC / AC	Project is only progressing at — % of the rate planned
	Critical Ratio	CR	CPI * SPI	Overall Performance of the Project
Predictors	To Complete Performance Index	TCPI	(BAC-EV) / (BAC-AC)	TCPI>1 indicates a need for increased performance for the remaining work in order to stay within budget
	Estimate At Completion	EAC	BAC / CPI	Currently estimate that total project will cost Rs. …
	Variance at Completion	VAC	BAC - EAC	Negative means - Contractor currently expect to be Rs.—over budget when the project is completed
	Estimate to Complete	ETC	EAC - AC	Contractor need to spend Rs.——— to finish the project (BAC -EV) / CPI
	Independent Scheduel at Completion	ISAC	BAC / SPI	Calculate final cost depending upon schedule performance at that date

ELEMENTS OF EARNED SCHEDULE MANAGEMENT

Actual Time (AT): This is the duration from the beginning of the project to status date.

Schedule at Completion (SAC): This is the original planned completion duration of the project.

Earned Schedule (ES): This is the duration from the beginning of the project to the date on which PV should have been equal to the current value of EV.

ES = % Complete x SAC

Time Variance (TV): The Time variance is a measure of schedule performance in time units rather than cost units.

TV = ES – AT

If this value is negative the project is behind schedule, and if it is positive it is ahead of

schedule. This is called schedule variance (time) SV (t).

Time Performance Index (TPI):

TPI = ES / AT

This is called schedule Performance Index (time), SPI(t), if TPI is greater than 1.0, the project is ahead schedule, and if it is less than 1.0, the project is behind schedule.

Forecasting of Time at Completion:

TEAC = SAC / TPI

This is gives the time estimate at completion with the same rate of doing work for the rest of the project.

Time Variance at Completion (TVAC):

The time variance at completion gives the an indication of the estimated amount of time that the project will be completed ahead or behind schedule.

TVAC = SAC – TEAC

In this equation, 0.0 indicates that the project is expected to complete on schedule, a positive value indicates that the project is expected to be completed ahead of schedule and a negative value indicates that the project is expected to be completed behind schedule.

ANALYSIS AND DECISION

By doing the analysis of Earned Value and Earned Schedule Management, a project manager can be confident the decision and action taken will have a much higher probability of success. Before moving on, a few words are needed concerning "Sufficiency of Data." This information is critical in controlling management's tendency to overreact. It is common knowledge we shouldn't react to insufficient data. But, sometimes the pressure to do something is overwhelming and we take action foolishly. Also, once a recovery strategy is implemented, we need to allow it time to be successful. It is not effective to amend and change strategies constantly; in fact, it is wasteful.

There are four basic actions:

No Action Required when performance is good

Investigate when there is insufficient data

Adjust/Realign Overtime or Personnel

- Renegotiate ....Cost, Schedule, or Requirements Connecting the analysis to the actions is certainly not too difficult for the first two items. When the project is performing well, the manager would be wise to not make any changes. Also, when the project has poor performance, but has insufficient data, it is prudent to investigate for potential causes and simply monitor the indicators for improvement.

The Adjust/Realign and Renegotiate actions are not so simply connected to the analysis results. The project manager should negotiate additional cost and/or schedule, or reduction of requirements, only when a recovery strategy is not possible, or there is insufficient time for the recovery to be effective. Adjustment, i.e., raising or lowering overtime or number of project personnel requires several inputs. It is the proper action when performance is poor, there is enough data to make an informed decision, a recovery strategy is possible, and there is sufficient time to execute it.

Careful realignment of personnel can yield increased efficiencies. However, the forecast effects of realignment cannot be quantified easily. It is recommended that this management action be used sparingly. Realignment can be an effective strategy when the values of CPI and SPI(t) are less than their respective ratios, but worse than their planned value (1.0).

CASE STUDY

The following case study illustrates the concepts discussed in this paper. Consider a construction of bunglow project that has baseline budget at completion of Rs. 46,60,000/- and baseline schedule of 7 months. The baseline indicates that by the end of month 4, the project is planned to be 58% complete. At the end of month 4, it is reported that 43% of the project work has been completed at a cost of Rs. 21,96,000/-.

By using EVM Method:

BAC = Rs. 46,60,000/-

AC =Rs. 21,96,000/-

AT = 4 Weeks

PV = 58% x Rs. 46,60,000/- = + Rs. 27,30,000/-

EV = 43% x Rs. 46,60,000/- = Rs. 20,04,000/-

Therefore :

% Complete = EV/BAC = 43%

% Spent = AC/BAC = 47.12%

Cost and Schedule Variances:

CV = EV - AC = - Rs. 1,92,000/-

SV = EV - PV = - Rs. 26,56,000/-

Performance Indices:

CPI = EV / AC = 0.91

SPI = EV / PV = 0.74

Estimate at Completion and Variance at Completion:

EAC = BAC / CPI = Rs. 51,21,000/-

VAC = BAC – EAV = - Rs. 4,69,000/-

Earned Schedule:

AT = 4 months

SAC = 7 months

ES = % Complete x SAC = 3.01 months

TV = ES – AT = - 0.99 months

TPI = ES / AT = 0.75

TEAC = SAC / TPI = 9.30 months

TVAC = SAC – TEAC = - 2.30 months

RESULTS AND DISCUSSION

From the above equations, extra cost is required to complete this projects is Rs. 4,69,000/- as well as from earned schedule analysis extra time required to complete the project is 2.30 months. Here, we can conclude that this project is in seriously trouble regarding both cost and schedule performance. Corrective actions required to be taken to complete this project within given cost and time.

CONCLUSION

Earned Value Management is a powerful methodology that helps executive, project manager, program manager and other stakeholders of the project to manage the project more effectively. Earned Schedule is an important extension to EVM that allows EVM metrics to be transformed to time or

duration metrics to enhance the evaluation of project schedule performance, forecast the duration needed to complete the project. It helps the project managers to understand the time estimates for the completion of the project, and provides further insights for making better decisions about the project schedule and other critical parameters.

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