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An Introduction to Earned Value Performance Management

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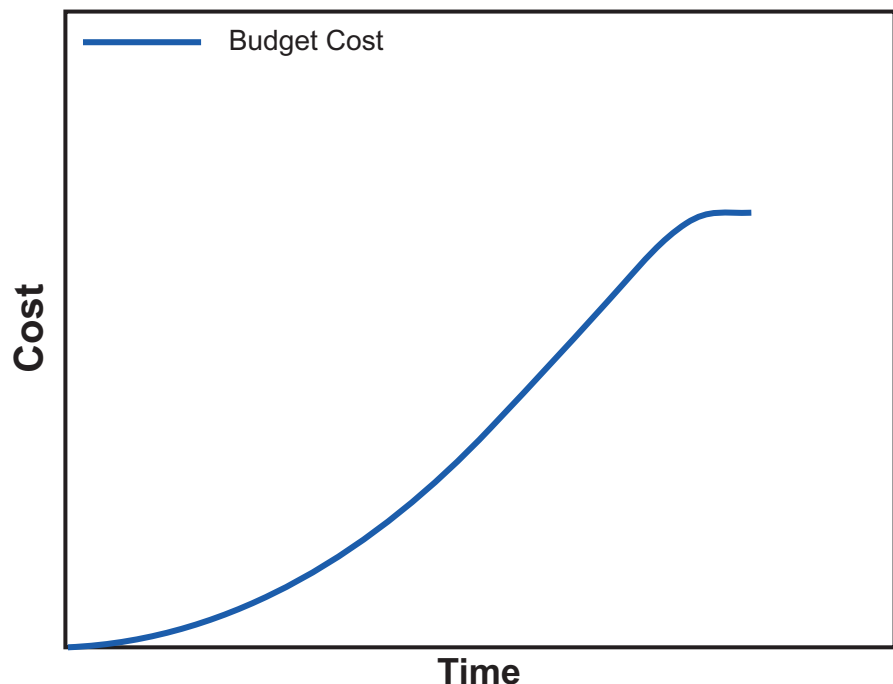
What is Earned Value?

Managers at all levels in an organisation need to know, especially if the work is not running according to schedule, the following key information:-

- How much work has actually been performed?
- How much has it cost?
- What is the estimate of the final cost?
- What is the expected completion date of the planned work?

This problem is illustrated in Figure 1 which shows graphical representation of a time phased work schedule. The blue line (Budget Cost) represents the cumulative budgeted cost for the work.

Figure 1



However, work rarely runs exactly to schedule, therefore, the manager also needs to know how work is progressing compared with the plan. Many managers have access to the actual costs that have been incurred for their work. This is shown as a red line in Figure 2. The red line (Actual Cost) represents the cumulative actual costs for the work done to date.

Figure 2

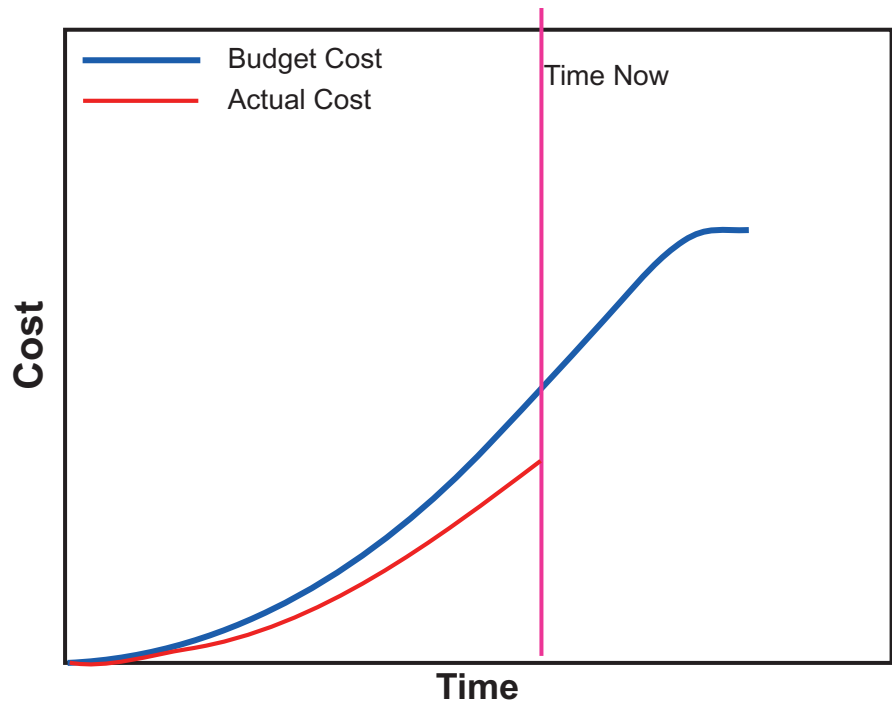
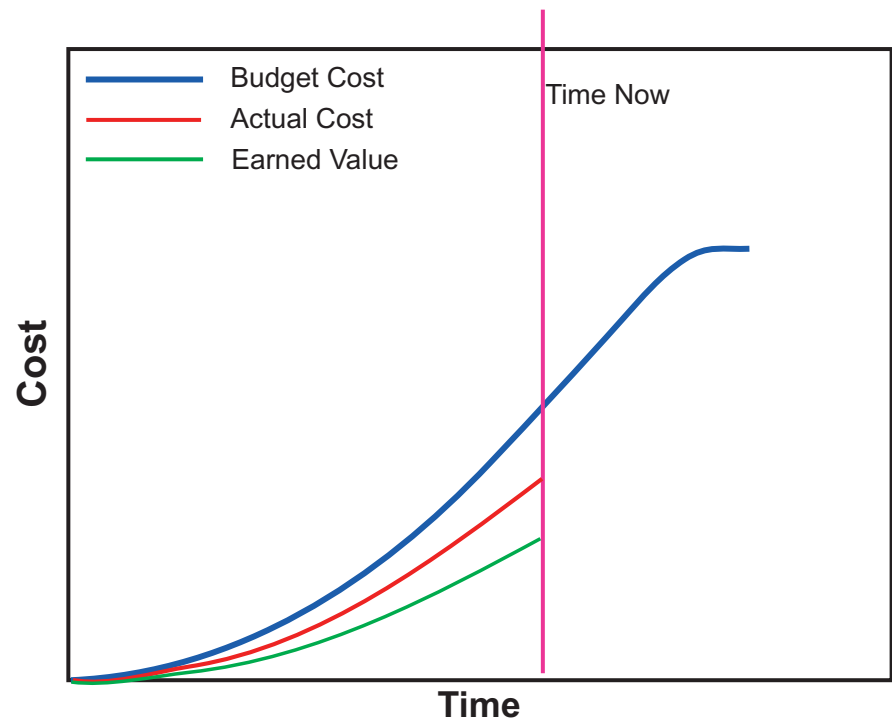


Figure 2 shows the cost of the work is running under budget. This information by itself may give the impression that the work will be completed under budget. However, the manager has very little idea of how much work has actually been performed. The actual expenditure may have been on tasks outside the original scope or it may have been spent inefficiently. To overcome this problem, the manager needs a third piece of information. This information is known as the Earned Value.

Figure 3



Earned Value is the value of completed work expressed in terms of the budget assigned for that work. This is shown as the green line in Figure 3.

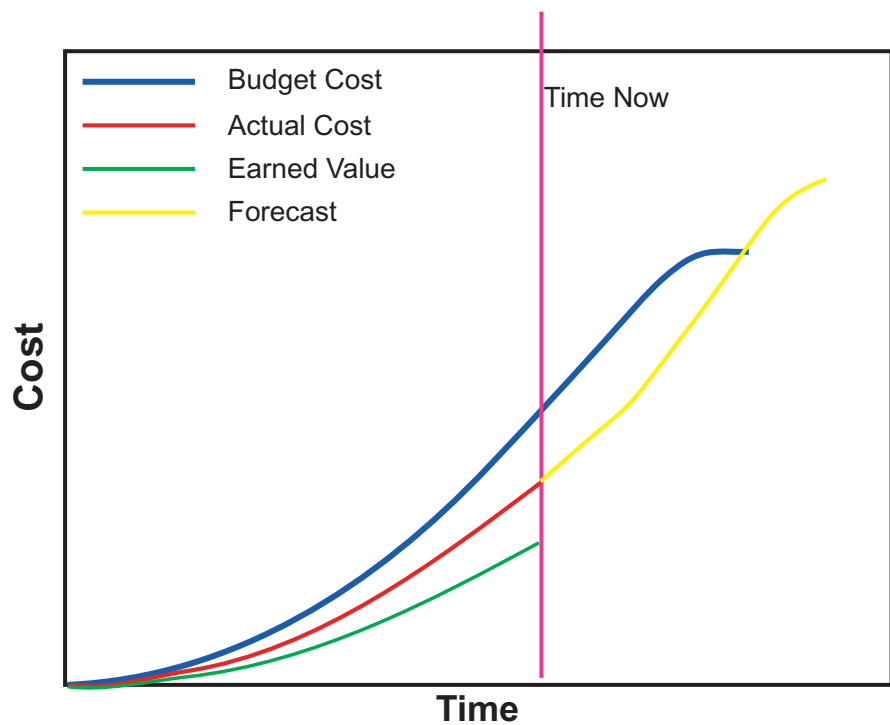
Figure 3 puts the work performance in a different light. The Earned Value (green line) is below the actual cost (red line). This means the project is spending more than was budgeted to achieve the work

performed to date (ie the work is being performed at a loss or is “running over cost”) This is contrary to the impression given in Figure 2.

Figure 3 also shows the Earned Value (green line) is below budgeted cost (blue line). This shows the project is running behind schedule. This could not have been recognised from Figure 2. This demonstrates the importance of knowing the Earned Value of the work actually performed in addition to the budget and actual cost.

The above information is hindsight. What managers also need is a reliable forecast of when the work will be completed and how much it will cost at completion. Earned Value enables such forecasts to be made. When the Earned Value is available, the manager knows how much work has actually been performed and what it has cost. Since they know from the original budget how much work there is in total, the amount of work remaining can be calculated and used to forecast the eventual cost and (in conjunction with the schedule) the completion date of the work. The forecast can take into account past performance rates and is shown as a yellow line in Figure 4.

Figure 4



By using a combination of schedule information (to project the remaining time needed to complete the project) and applying the cost performance ratio achieved to date to all unexpended budgets, a reliable projection of the cost and time to complete the project can be established.

The Basic Concepts of Time Phased Budgets and Earned Value

There are three keys to success in using Earned Value Performance Measurement:

- 1 Work must be planned in such a way that objective measurement of achievement is possible.
- 2 Objective techniques must be selected in advance to measure ‘achievement’ for each piece of work.
- 3 Cost, schedule and technical achievement aspects of the project should not be managed in isolation (ie a single integrated management system is required).

Setting up a project for Earned Value Performance Measurement requires a suitable decomposition of the work, establishment of a Work Breakdown Structure, identification of personnel to be assigned responsibility, scheduling the work and assignment of resources and corresponding costs/budget to the work.

In this example, it is assumed that the Outline, Draft and Acceptance of the Specification are scheduled to occur in succeeding months and are assigned a value of \$1000 each (refer Blue). This process has established a baseline in the form of a time phased budget for each element of work (aka Planned Value) which can be plotted. This is the Performance Measurement Baseline.

When the Specification is completed, it can be said that it Earned the Value of \$3000 against the plans; or more simply, ‘Earned Value equals \$3000’ (refer Green). The actual cost of the specification is not required in order to determine the Earned Value, EV is predetermined during the planning process.

Note, ‘Outline’ started and finished on time; it was planned to finish in month 1 and actually finished in month 1. ‘Draft’ started on

Write Specification

Month	1	2	3	4
Outline	█			
Draft		█		
Review & Accept			█	
Planned Value	1000	1000	1000	
Earned Value				
Actual Cost				

Write Specification

Month	1	2	3	4
Outline	█ █			
Draft		█	█	
Review & Accept			█	█
Planned Value	1000	1000	1000	
Earned Value	1000	500	500	1000
Actual Cost				

Write Specification




Month	1	2	3	4
Outline	█ █			
Draft		█	█	
Review & Accept			█	█
Planned Value	1000	1000	1000	
Earned Value	1000	500	500	1000
Actual Cost	800	800	300	900

time and finished one month late. It was planned to finish in month 2 but actually finished in month 3. 'Review and Acceptance' also finished one month late; it was planned to finished in month 3 but actually finished in month 4.

The direct costs incurred in developing the specification are collected separately, these are called the 'Actual Cost' (refer Red). Actual Costs need to be accumulated in the same time periods as the Earned Value but are not directly related to Earned Value. Actual Costs may be higher or lower than the budget for the work being accomplished.

As work progresses schedule and cost variances can be measured from the plan in dollar terms. Deviations from the plan identified, and the results reported in tables and charts (refer below).

Write Specification

Month	1	2	3	4
Outline				
Draft				
Review & Accept				

Cumulative Values

Planned Value	1000	2000	3000	
Earned Value	1000	1500	2000	3000
Actual Cost	800	1600	1900	2800

In this example, the cost "blow out" in month 2 was successfully recovered in month 3.



The Effect of 'Objective Measures and Aligning Costs

The shape of the graphs in the previous section can change significantly depending on the 'Objective Measures' chosen for the project (or tasks). The charts in the previous section are based on the Earned Value being achieved on a progressive basis (ie when a task is half done, 50% of the EV is accomplished).

However, accurately assessing the status of documentation is notoriously difficult. Therefore it would be quite reasonable to make the objective measure for these tasks "100% on completion", ie no earned value is achieved until the task is complete.

This would mean no Earned Value is achieved during ‘Month 2’ because no task was finished during that month.

Aligning Actual Costs (AC) with Earned Value (EV)








To keep the performance reporting accurate, the Actual Costs included in each period (month) needs to be accumulated on the same basis as the Earned Value. Accumulating Actual Costs in ‘Month 2’ for the preparation of the “Draft” would show a large negative Cost Variance (because there is no corresponding EV); this would be incorrect. All of the Actual Costs for preparing the “Draft” need to be accumulated in Month 3, at the same time the EV for preparing the “Draft” is accumulated.

In addition to the fundamental need to align AC with EV by using the same ‘Objective Measures’, two administrative issues need to be considered on most projects:-

- ◆ Prepaid costs (eg annual insurance premiums) need to be deferred to align with the work that is generating the EV.
- ◆ Some form of “accrual” process is needed to account for costs incurred in generating the EV (ie doing the work) for which accounts have not been received and/or paid.

The effect of these changes is shown in the Chart below. The difference in the shape of the curves between the two charts is the fundamental reason why it is important to establish the way EV will be calculated (the ‘Objective Measures’) before work commences on the project and for this information to be widely communicated.

Write Specification

Month	1	2	3	4
Outline	 			
Draft		 		
Review & Accept			 	

Cumulative Values

Planned Value	1000	2000	3000	
Earned Value	1000	1000	2000	3000
Actual Cost	800	800	1900	2800



Earned Value - Stages of Development

- 1 Decompose the Project Scope** Decompose the entire project scope of work into manageable elements using a Work Breakdown Schedule (WBS).

- 2 Assign Responsibility** Assign responsibility for the accomplishment of each element of the work at an appropriate management level. An Organisation Breakdown Structure (OBS) may be used to identify the organisational hierarchy responsible for work accomplishment. A Responsibility Assignment Matrix (RAM) may be used to map WBS elements to the OBS elements.

- 3 Schedule the Work** Create a schedule for all the work which identifies tasks, milestones and interdependencies. Tasks are created at or below the level of work elements in the WBS. All elements of the work are to be scheduled into a logical sequence which identifies tasks, milestones and interdependencies. The goal of the schedule is to provide a vehicle for evaluating actual progress (in time) against predefined objective measures of achievement. All tasks and milestones within the project should be linked with dependencies to produce a logic network that will allow the critical path, free float and total float for every task and milestone to be calculated.

- 4 Develop a Time-Phased Budget** Assign resources (and costs) to scheduled tasks and establish the time-phased budget. Tasks have a budget value assigned which is distributed over the activity duration and expressed in terms of dollars, labour hours, or other measurable units. Budgets should be assigned to all work elements (tasks) within a project. The time-phased budget at the detail level is defined as the Planned Value (PV). The total budget at the completion of the project is termed the Budget at Completion (BAC).

The time phased representation of the total Planned Value (PV) for all tasks (or WBS elements) is the Performance Measurement Baseline (PMB). The PMB represents the formal plan for the project manager to do all of the project work in the amount of time allocated and within the amount of budget authorised to accomplish that work.

Generally, additional funds are set aside as a Management Reserve (or contingency) for any unanticipated tasks that are within the scope of the project.

The total budget for resources assigned to the project is required to equal the Budget At Completion (BAC) of the Performance Measurement Baseline. The budget at completion plus management reserve should equal the Project Budget (PB)

5 Assign Objective Measures of Performance

The accomplishment of tasks is ultimately expressed in terms of their budgetary values (Earned Value). Objective measures of performance, are used to quantify the degree of completion of tasks in progress. These measure of performance should be established in such a way that they correctly measures accomplishment of in-progress tasks. The measuring of Earned Value should be computed using the same methodology as the original plan (budget). The resulting metric is referred to as the Earned Value (EV).

Objective measures allows work achievement to be measured in a clear and unequivocal way. Setting the objective measures in advance enhances accountability and objectivity.

6 Set the Performance Measurement Baseline

The Work Breakdown Structure, the Schedule, the Budget for each task and element and the time-phased budget as developed in steps 1-5 shall be approved by the Project Manager or higher authority and recorded as the Performance Measurement Baseline (PMB). This baseline provides the reference points against which actual project progress is compared, it should include the best estimates for task duration, scheduling, resource allocation, costs, and the other project variables required to be monitored.

To be valid a baseline, it should not only be logically constructed but it should make sense when compared to available project resources. A quick way to judge this is to plot

S-Curve. Ob-

serving the steepness of the S-Curve can indicate whether or not the baseline is feasible. If the slope of the curve is very steep it indicates a short duration and it may not be possible for project resources to be ramped up that quickly.

7 Perform the Work

Formally authorise all work to be undertaken and perform the work. In order for the Project Manager to exercise proper control of the project, the chain of authorisation for the commencement of work should emanate from the Project Manager either directly or indirectly. The work authorisation should clearly identify:

- What is to be done.
- Who is to do it.
- When it is to be done.
- The quantity of resources budgeted.
- Who is the person responsible for acceptance of the work.
- How progress and actual costs are to be aggregated.

8 Accumulate and Report Performance Data

Record and accumulate schedule progress, earned value and actual cost for each task on a consistent and periodic basis. Their Planned Value, Earned Value, Actual Costs, Budget at Completion and Estimate to Complete are calculated and logically summarised through the project decomposition (WBS) to properly

represent the status of the individual tasks and the project in total. In addition the current schedule needs to be progressed to show achievement and to provide forecast completion dates for the scheduled work.

The Earned Value (EV) is compared with the Planned Value (PV) to establish the Schedule Variance (SV).

All costs actually incurred in the performance of the tasks (AC) should be accumulated at a level which will identify the cost elements and factors contributing to cost variances. The Actual Costs (AC) is compared with the Earned Value (EV) to establish the Cost Variance (CV).

Forecasts at completion both in terms of cost and schedule are made for comparison with current period status information and performance Reports are distributed to appropriate management levels on a consistent and periodic basis.

9 Analyse Project Performance

Identify and analyse variances from the Performance Measurement Baseline (PMB).

Earned Values (EV) for tasks, elements, and totals are compared with the corresponding Planned Value (PV) to identify any variance between the amount of work accomplished and the amount of work scheduled. $Schedule\ Variance\ (SV) = EV - PV$. A positive value is good, more work has been done than planned, a negative value indicates production is behind the plan.

The progressed (current) schedule is compared with the baseline schedule to determine slippages and forecast completion dates.

Earned Value (EV) for tasks and work elements is compared with the corresponding Actual Cost (AC) to determine the Cost Variance (CV). $CV = EV - AC$ a positive value is good, the work has been done for less than the budget. A negative value indicates cost overruns.

Cost and schedule variances should be evaluated to determine their cause and the likely impact on the project.

Estimates of the costs at completion should be routinely developed and updated based on past trends and current knowledge and compared with the corresponding Budget At Completion (BAC) to identify the extent of the cost Variance at Completion (VAC). Forecasts of the scheduled completion should also be routinely developed and updated based on past trends and current knowledge for comparison with the planned completion dates.

10 Management Action

Take management action to compensate for past deviations or to rectify projected deviations from the Performance Measurement Baseline. The required corrective action should be determined based on the source and cause of the variance.

Variances may have several dimensions. They may arise from poor planning, unforeseen scope changes, technical problems, equipment failures or other exogenous factors such as supplier difficulties.

Regardless of the cause, corrective actions require either a change in the baseline planning or the development of a short term get well plan that is incorporated in the forecasts. In either case, revisions to planning should only be accomplished prospectively. Retroactive changes to cost, schedule or technical planning or accomplishment should not be allowed other than to correct administrative or typographical errors.

11 Baseline Maintenance

Changes to the Performance Measurement Baseline can originate either internally through the identification of unforeseen scope changes or resource requirements or where changes have been directed from other stakeholders. Where there have been changes to the project, it will be necessary to replan certain elements of the work. Due to the importance of maintaining a valid baseline for performance measurement, replanning should be accomplished:

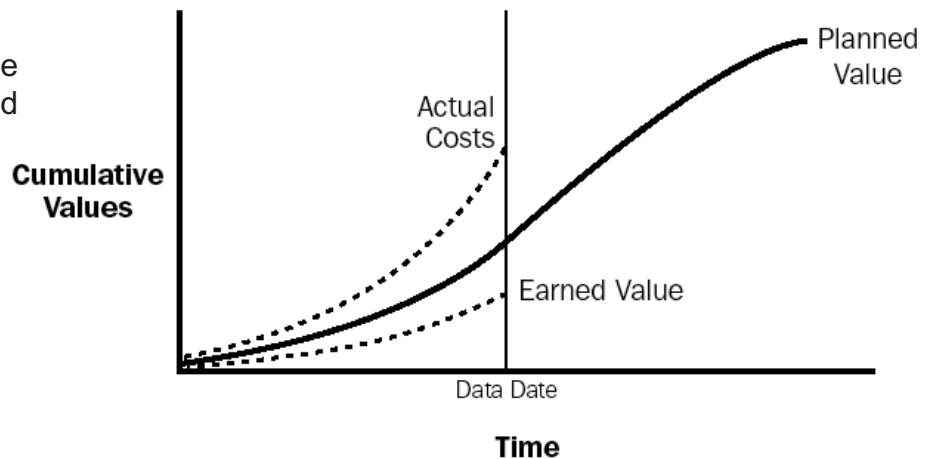
- with proper authority;
- in a systematic and timely manner;
- should be carefully controlled; and
- adequately and visibly documented.

Replanning should not be used as an alternative to proper initial planning, nor should it be used to mask legitimate variances.

Maintenance of the Performance Measurement Baseline is required to ensure that baseline changes are properly recorded and visible and can be examined to determine their causes and potential impact on completion dates and costs. In order to maintain the integrity of the Performance Measurement Baseline the project manager should not transfer scope or budgets independently of one another.

Earned Value Presentation, Definitions & Calculation

The S-Curve Charts are derived from tabulated project data.



WBS Element	Planned	Earned	Cost					Performance Index	
	Budget	Earned Value	Actual Cost	Cost Variance		Schedule Variance		Cost	Schedule
	(\$)	(\$)	(\$)	(\$)	(%)	(\$)	(%)	CPI	SPI
	(PV)	(EV)	(AC)	(EV - AC)	(CV ÷ EV)	(EV - PV)	(SV ÷ PV)	(EV ÷ AC)	(EV ÷ PV)
1.0 Pre-Pilot Plan	63,000	58,000	62,500	-4,500	-7.8	-5,000	-7.9	0.93	0.92
2.0 Checklists	64,000	48,000	46,800	1,200	2.5	-16,000	-25.0	1.03	0.75
3.0 Curriculum	23,000	20,000	23,500	-3,500	-17.5	-3,000	-13.0	0.85	0.87
4.0 Mid-Term Evaluation	68,000	68,000	72,500	-4,500	-6.6	0	0.0	0.94	1.00
5.0 Implementation Support	12,000	10,000	10,000	0	0.0	-2,000	-16.7	1.00	0.83
6.0 Manual of Practice	7,000	6,200	6,000	200	3.2	-800	-11.4	1.03	0.89
7.0 Roll-Out Plan	20,000	13,500	18,100	-4,600	-34.1	-6,500	-32.5	.075	0.68
Totals	257,000	223,700	239,400	-15,700	-7.0	-33,300	-13.0	0.93	0.87

Note: All figures are project-to-date.

Basic EV Data

Planned Value (PV)

Otherwise called Planned Budget and (now outdated term) Budgeted Cost of Work Scheduled (BCWS). The authorised budget for the project work scheduled. Distributed over time (cumulative) using the Performance Measurements Baseline (PMB) schedule to generate the baseline S-Curve.

Earned Value (EV)

Otherwise called (now outdated term) Budgeted Cost of Work Performed (BCWP). The authorised budget for the project work actually accomplished based on the values in the PMB.

EV is calculated by applying the agreed performance measures to tasks in progress. EV is 0% for tasks not started and 100% for tasks that are completed.

Actual Cost (AC)

Otherwise called (now outdated term) Actual Cost of Work Performed (ACWP). The actual cost of work performed as recorded in the organisations cost accounts. It is important that the actual costs are gathered “as at” the same date as the Earned Value data and are the total authorised costs incurred at that date.

Basic EV Data

Budget At Completion (BAC)

The total authorised budget for accomplishing the scope of work as documented in the PMB. (Management Reserve is not included.) BAC can refer to a task, an element of the WBS (at any level) or the whole project.

Estimate At Completion (EAC)

The estimated total cost to complete the project's scope. It is the Actual Cost to Date + Estimate To Complete. EAC can refer to a Task, an element of the WBS (at any level) or the whole project.

Estimate To Complete (ETC)

Otherwise called Forecast Cost. The anticipated cost to complete all unfinished work on the project. This can simply be the unexpended budget (ie BAC - EV) or the unexpended budget adjusted by a factor to allow for trends experienced to date (see IEAC).

Independent Estimate At Complete (IEAC)

IEAC is a cost estimate generated by an independent process to calculate an adjusted completion cost based on trends to date. Options for calculating the IEAC include:

Assuming future cost performance will be the same as the past

$$IEAC = \frac{ACWP + (BAC - EV)}{CPI} = \frac{BAC}{CPI}$$

Assuming future cost performance will be influenced by factors of 80% past cost and 20% past schedule performance

$$IEAC = \frac{ACWP + (BAC - EV)}{0.8 \times CPI + 0.2 \times SPI}$$

Assuming future cost performance will be influenced by the last 3 months cost performance

$$IEAC = \frac{ACWP + 3 \times (BAC - BCWP)}{CPI1 + CPI2 + CPI3}$$

Assuming future cost performance will be influenced by past cost and schedule performance

$$IEAC = \frac{ACWP + (BAC - BCWP)}{CPI \times SPI}$$

Simply repricing (Reestimating) the incomplete portion of the project's work is NOT an acceptable option for EV calculations.

EV Variances

Cost Variance (CV)

The value of work performed less the cost of performing the work.

$$CV = EV - AC$$

Illustration: Developing the detailed design has a budgeted value of \$20 000. The job is now complete (100%), therefore the EV is \$20 000. The designer has invoiced \$19 500 for the whole of

the work ($AC = \$19\,500$ {it does not matter if the invoice has actually been paid yet, the costs have been incurred}).

The Cost Variance is: $CV = \$20\,000 - \$19\,500 = +\$500$

Note: to calculate the cost performance during a particular period, it is not necessary to know how much work was originally planned to be achieved in that period.

Schedule Variance (SV)

The difference between the value of work planned to be completed in a period and the value of work actually completed in the period (measured in PMB units).

To measure schedule performance during a specific period, the value of the work planned to be achieved during that period must be known, ie the Planned Value (PV). Then schedule performance is determined by comparing Earned Value (EV) with Planned Value (PV). Any difference is referred to as a Schedule Variance (SV).

The Schedule Variance is: $SV = EV - PV$

Illustration: \$20 000 worth of work was scheduled for the month of January ($PV = \$20\,000$). For whatever reason, only \$18 000 worth of work was achieved ($EV = \$18\,000$).

Then: $SV_{(\text{January})} = \$18\,000 - \$20\,000 = -\$2\,000$

Note: in order to calculate the schedule performance during a particular period, it is not necessary to know the cost of the work achieved (AC) only the budgeted cost for that work (from the PMB).

Note also that Earned Value data does not give a direct expression of days ahead or behind schedule. The schedule variance is expressed in terms of value of the work; an update (or status) of the project schedule is necessary to relate this to a calendar. Understanding the nature of the work causing the SV is important. For example, a negative SV due to nonreceipt of material might be recovered very quickly (the material is delivered); while a similar negative SV due to loss of production due to weather is unlikely to be recovered without management intervention. A negative SV indicates the project is behind schedule, the quantum of the slippage can only be accurately determined analysing actual progress data on the project schedule.

Lastly, note that Earned Value (EV) is essential to derive cost and schedule performance: the other two elements – Planned Value (PV) and Actual Cost (AC) render no useful performance information without Earned Value.

EV Performance Indices

Cost Performance Index (CPI)

The cost efficiency ratio of Earned Value (EV) to Actual Costs (AC) over a specified period. A value greater than 1 indicates the work is being performed in a more cost effective way than planned. A value less than 1 indicates actual costs are higher than the budgeted allowance for the work performed.

$$\text{CPI} = \frac{\text{EV}}{\text{AC}}$$

Schedule Performance Index (SPI)

The schedule efficiency ratio of Earned Value (EV) to Planned Value (PV) over a specified period. A value greater than 1 indicates more work is being performed than planned. A value less than 1 indicates less work is being performed than planned (ie the project is behind schedule).

$$\text{SPI} = \frac{\text{EV}}{\text{PV}}$$

Cost Variance % (CV%)

The Cost Variance expressed as a percentage of Earned Value.

$$\text{CV}\% = \frac{\text{CV}}{\text{EV}} \times 100$$

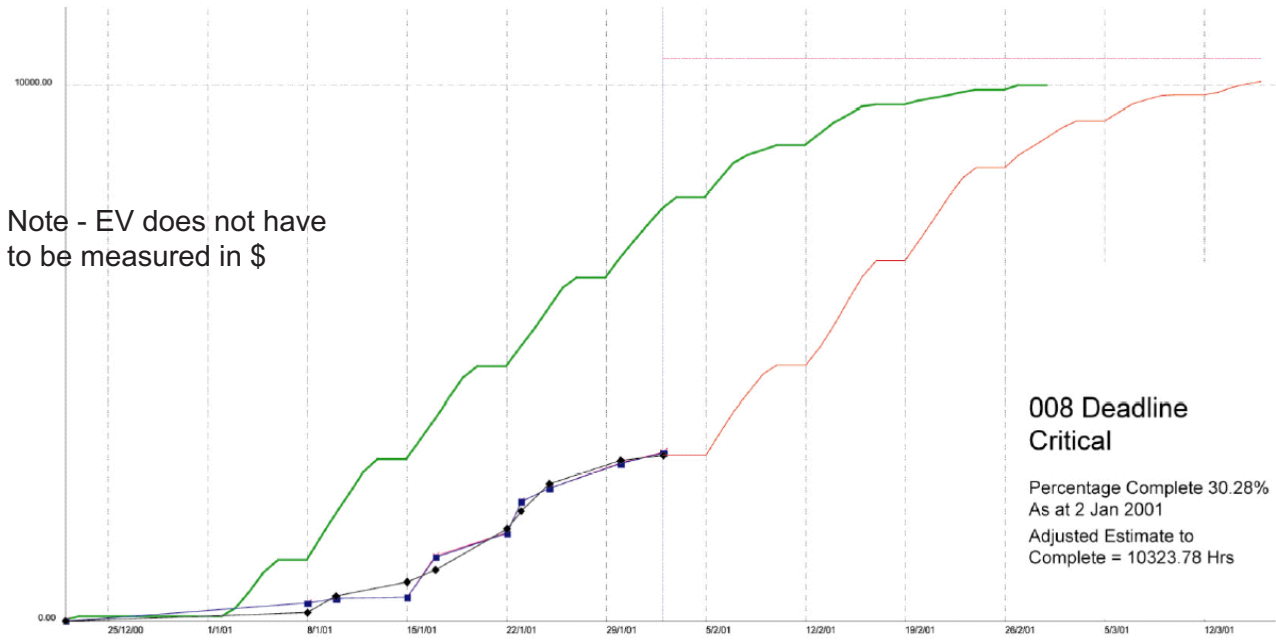
Schedule Variance % (SV%)

The Schedule Variance expressed as a percentage of Planned Value.

$$\text{SV}\% = \frac{\text{EV}}{\text{PV}} \times 100$$

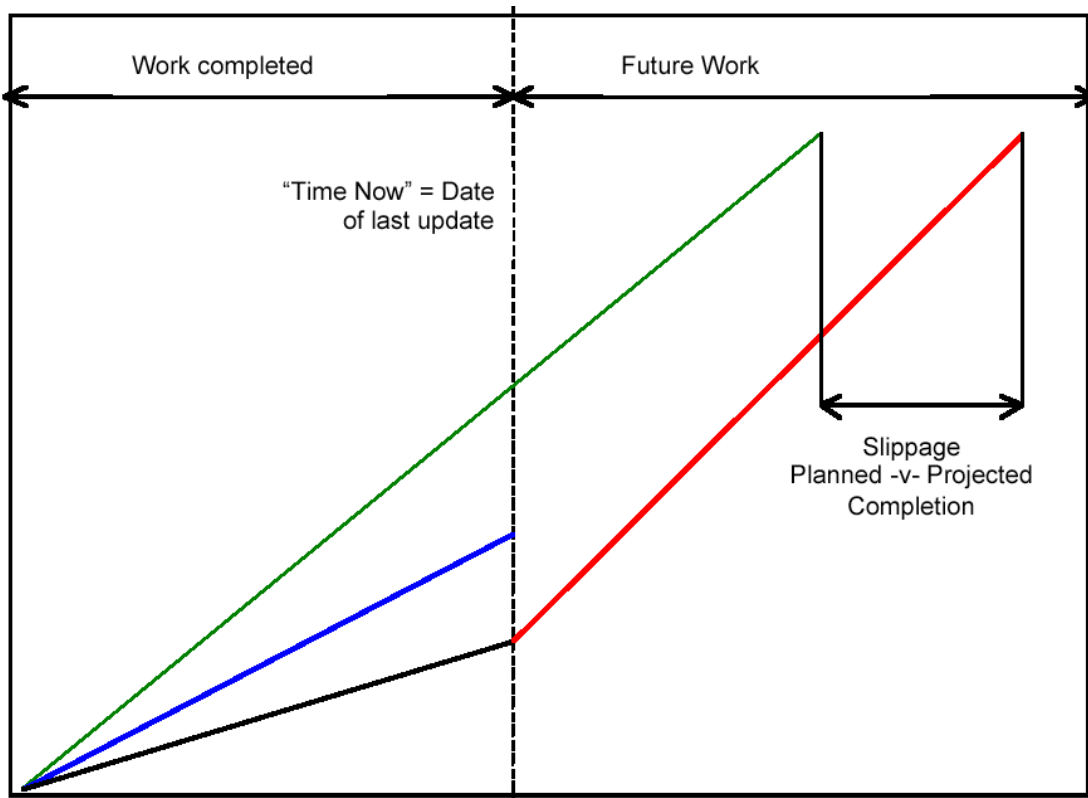
Interpreting EV Data

Planned -v- Actual Hours



A typical EV Chart (S-Curves) produced by most competent software packages encapsulates a vast amount of data to provide management with a complete overview of the project.

Time Related Data



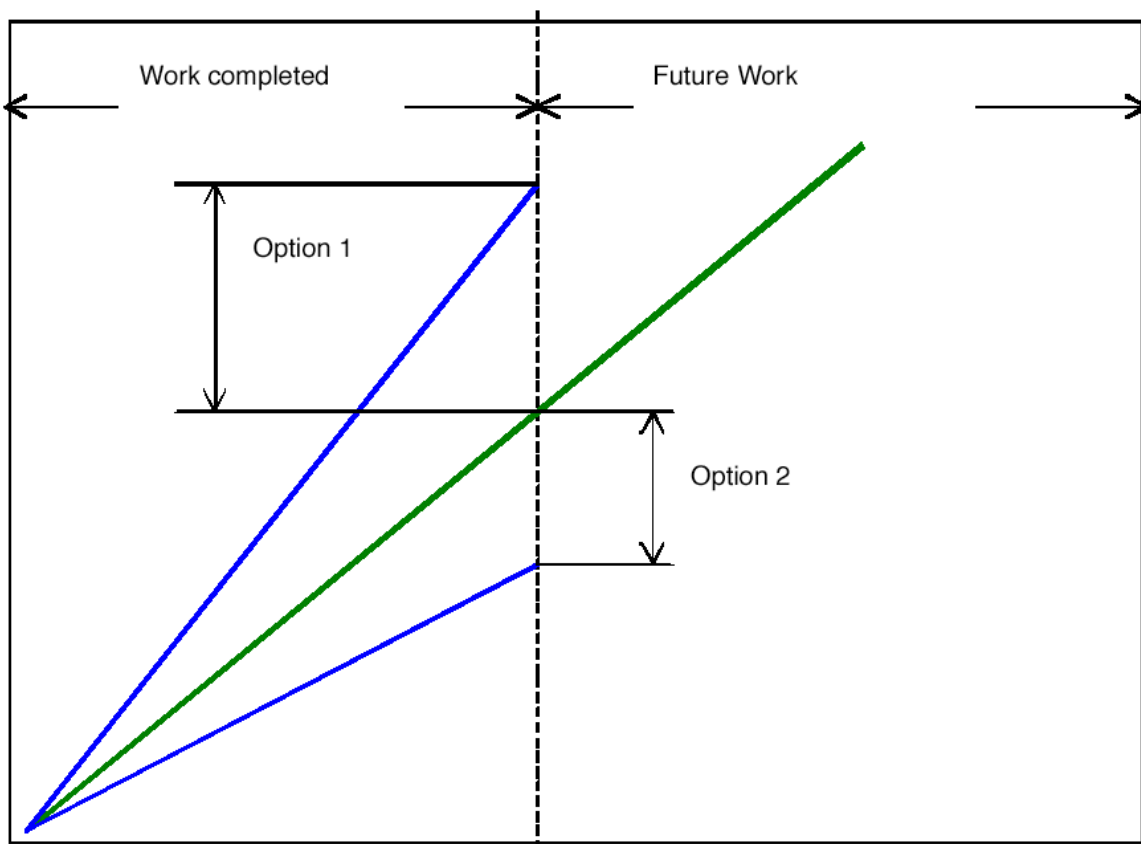
A vertical dashed line positioned at the date of the last update separates actual data input by the project team from forecast data, based on information contained in the schedule.

The thick (green) line plots the original planned expenditure on the project from its start to its original projected end date.

The thin (red) line plots the current expected expenditure required to complete the unfinished portion of the project.

The horizontal difference between the end of the thick line and the end of the thin line is the “Slip-page” (gain or loss) between the current expected completion date for the project and the original planned date.

Budget Related Data



The thick (green) line plots the original planned expenditure on the project. This is the original budget required to complete all of the work on the project.

The thin (blue) line plots the value of work achieved through to the last update.

The difference between these two lines (and how they are trending relative to each other) shows if an adequate **quantity** of work is being achieved on the project.

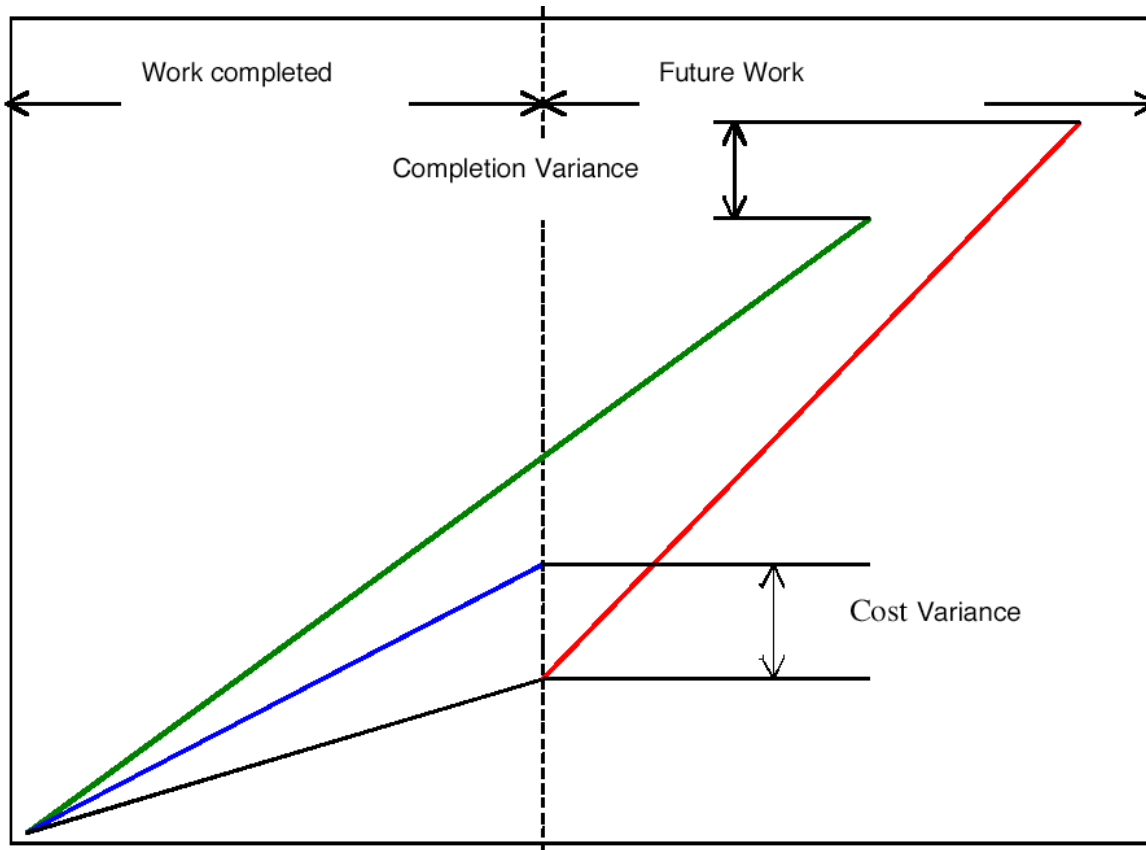
Option 1 shows a situation where the value (quantity) of work actually achieved is greater than the quantity planned to be achieved to date.

Option 2 shows a more usual situation where the value (quantity) of work achieved is less than the quantity planned to be achieved to date.

Comments

The value of work achieved (Earned Value) is based on the original plan. At the end of the project, the Earned Value will be 100% of the original budget; among other things, this can be used to calculate the percentage complete

Cost Related Data.



The thin (black) line tracks the actual expenditure to date (Actual Cost) on the project to achieve the work recorded as completed.

The thin (red) line projects the anticipated expenditure required to complete the project from the last update through to completion.

The difference between the black and the blue lines (Actual Cost of the work performed (AC) -v- Earned Value (EV) of the work performed) shows how efficiently the work achieved to date has been performed to date.

The Variance at completion (ie the vertical difference between the top of the red line and the top of the green line) shows the expected over run (or under run) of costs compared to the original budget at the completion of the servicing.

Notes

The value of this chart is in watching the trends develop over time. Generally a change in an established pattern is caused by an identifiable change in the project’s operating environment.

Similarly, to cause a desirable change in the trends, specific changes in the project need to be made. Research in the USA suggests that the CPI on a project will vary by less than 5% after the first 20% of a project and usually only in a negative direction.