An Introduction to Earned Value Management

What is Earned Value?

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

- How much work has actually been performed?
- How much has it cost?
- What is the estimated 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 planned value for the work. Without additional data there is no information to help manage the work. Work rarely runs exactly to plan, therefore to manage, the manager needs to know how the work is actually progressing compared with the plan.

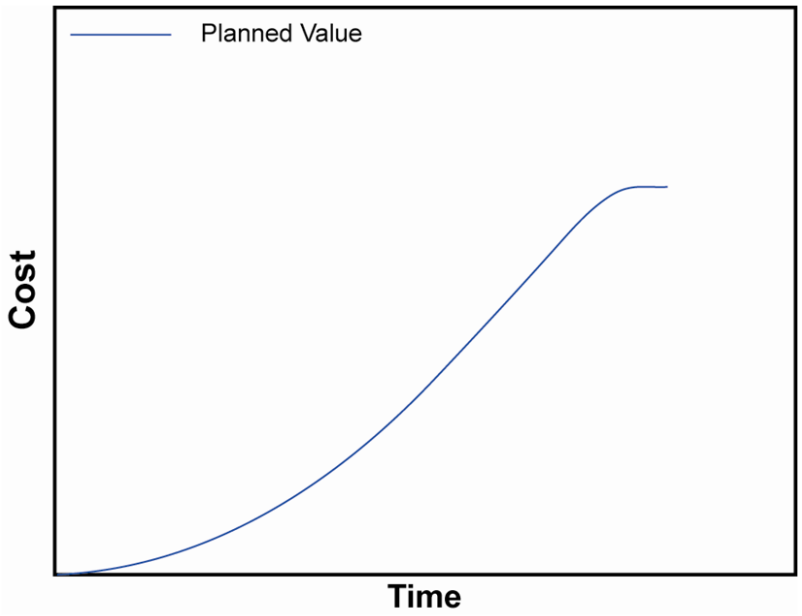


Figure 1

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 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, alternatively it may be running behind schedule. Based in this infomration, 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.

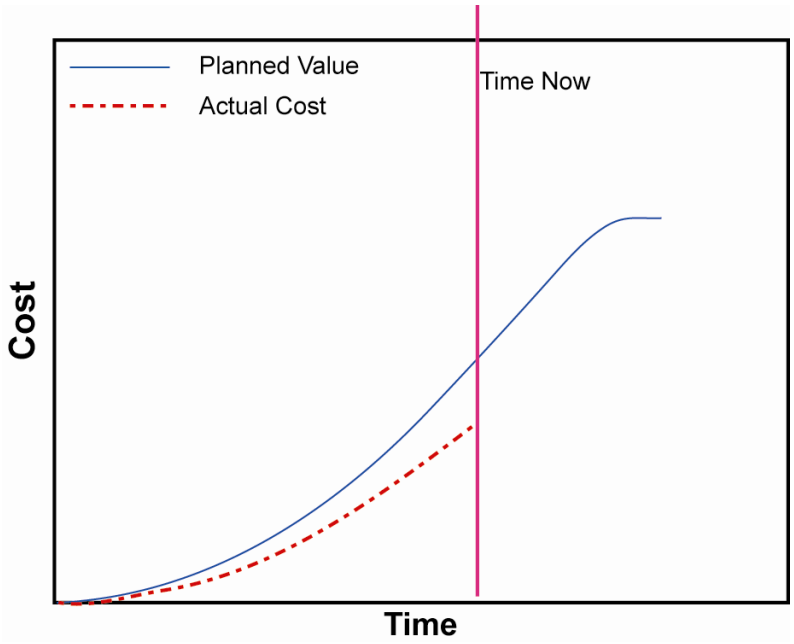


Figure 2

Earned Value is the value of completed work expressed in terms of the budget assigned for that work – how much of the 'blue line' has actually been accomplished? This is shown as the green line in Figure 3.

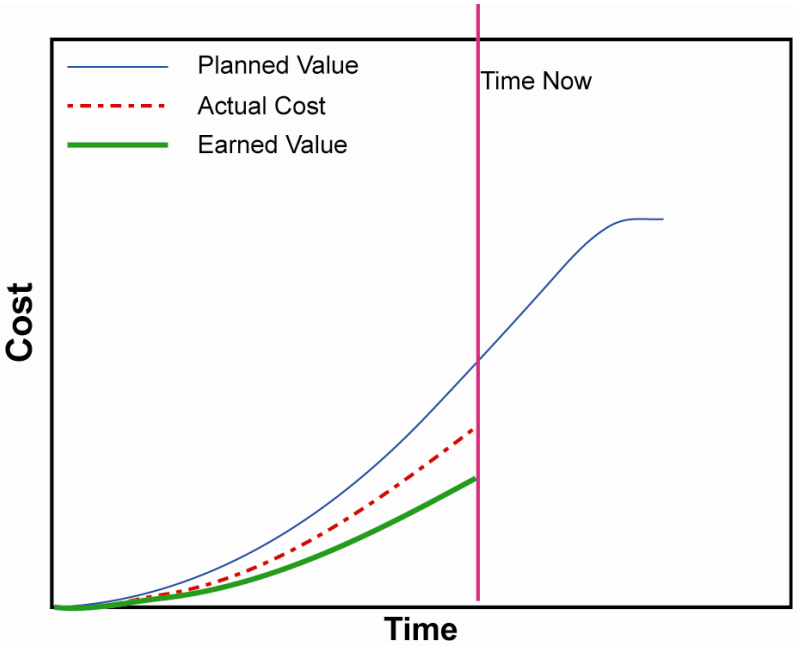


Figure 3

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 may be contrary to the impression given in Figure 2.

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

All of 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 Management Systems enable these forecasts to be made with a reasonable degree of accuracy. When the full set of Earned Value information 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 takes into account past performance rates and is shown as a yellow line in Figure 4.

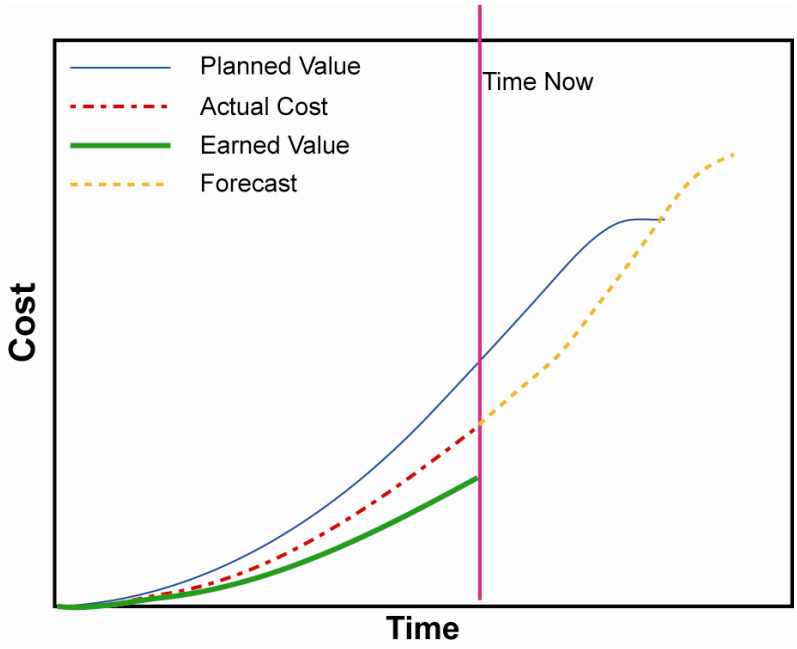


Figure 4

By using a combination of schedule information[1] (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 Management:

1. Work must be planned in such a way that objective measurement of achievement is possible
2. These 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 be managed in a single integrated management system.

[1] **Earned Schedule** is an extension to EVM that uses EV data to predict completion times.

Setting up a project for Earned Value Management requires:

- A suitable decomposition of the work using a Work Breakdown Structure[2]
- The identification of personnel to be assigned responsibility for accomplishing the work
- The scheduling the work, including the assignment of resources, and the corresponding costs/budget for 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 planning process has established a baseline in the form of a time phased budget for each element of work, the Planned Value (PV). Once approved, this becomes the Performance Management Baseline (PMB).

When the Specification is completed, it can be said that the project *has Earned the Value* of $3000 against the plan; 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), EV is directly aligned to the PV.

Note, 'Outline' started and finished on time; it was planned to finish in month 1 and actually finished in month 1. 'Draft' started on time and finished one month late. It was planned to finish in month 2 but actually finished in month 3. 'Review and Acceptance' was performed in the time planned, but was delayed one month; 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 (AC - refer Red). Actual Costs need to be accumulated in the same time periods as the Earned Value but are not directly related to the EV. Actual Costs may be higher or lower than the budget for the work being accomplished.

Write Specification

Month	1	2	3	4
Outline				
Draft				
Review & Accept				

Cumulative Values

Planned Value	1000	2000	3000	

Month	1	2	3	4
Outline				
Draft				
Review & Accept				

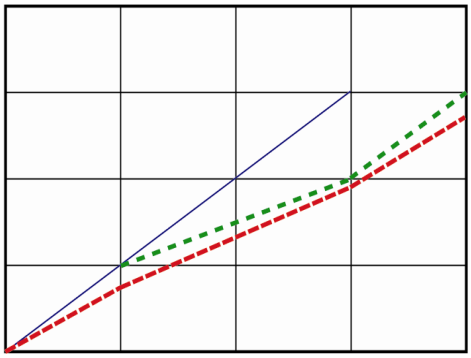
Cumulative Values

Planned Value	1000	2000	3000	
Earned Value	1000	1500	2000	3000

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	1350	1900	2800



[2] For more on the ***WBS*** see: https://www.mosaicprojects.com.au/WhitePapers/WP1011_WBS.pdf

As work progresses schedule and cost variances can be measured from the plan in dollar terms each month, deviations from the plan identified, and the results reported in tables and charts.

The Effect of 'Objective Measures[3]' and Aligning Costs

The shape of the graphs in the previous section can change significantly depending on the 'Objective Measures of Performance' 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)

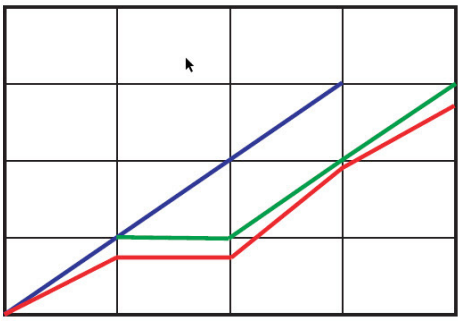
To keep the performance reporting accurate, the Actual Costs included in each period (month) needs to be accumulated on the same basis as the Earned Value. Accumulating Actual Costs in 'Month 2' for the preparation of the "Draft" would show a large negative Cost Variance (because there is no corresponding 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.

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



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 above. 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

[3] ***Objective measures*** for a single work package may be based on:
- Discrete effort, measuring the units produced
- Weighted milestones, based on the accomplishment of distinct phases of the work
- Fixed formula (percentages attributed at the start and end), typically 0/100, 50/50, or 100/0
- Percent complete
- 'Apportioned effort' or 'level of effort', where the work cannot be measured directly.

'Objective Measures') before work commences on the project and for this information to be widely communicated.

Earned Value – Stages of Development

1 Decompose the Project Scope

Decompose the entire project scope of work into manageable elements using a Work Breakdown Structure (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 of the work. Schedule tasks are created at or below the lowest level in the WBS. 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].

4 Develop a Time-Phased Budget

Assign resources (and costs) to work packages or schedule tasks and establish the time-phased budget. The assigned budget value is distributed over the activity duration based on the 'objective measure' and is expressed in terms of dollars, labour hours, or other measurable units. Budgets should be assigned to all work elements (tasks or work packages[5]) within a project. This time-phased budget defines the Planned Value (PV) curve. The total budget at the completion of the project is termed the Budget at Completion (BAC).

Once approved, the time phased representation of the total Planned Value (PV) for all tasks (or WBS elements) becomes the Performance Management Baseline (PMB). The PMB represents the formal plan for the project manager to accomplish all of the project work in the time allocated and within the amount of budget authorised for 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 Management Baseline. The budget at completion plus management reserve should equal the Project Budget (PB).

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4 For more on ***good scheduling practice*** see: https://mosaicprojects.com.au/PMKI-SCH-010.php

5 In many situations, cost and EV are more efficiently managed at the work package level. Whereas the scheduling of work and the use of resources required a more detailed schedule. Integration between the two systems is essential.

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 or work packages in progress. These measures of performance should be established in such a way that they correctly measure accomplishment of progress. The measuring of Earned Value should be computed using the same methodology as the original plan (budget).

6 Set the Performance Measurement Baseline

The Work Breakdown Structure, the Schedule, the Budget for each task and WBS 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 Management 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 should not only be logically constructed but should also make sense when compared to the available project resources. A quick way to judge this is to plot an S-Curve. Observing the steepness of the S-Curve can indicate if the baseline is feasible.

7 Perform the Work

Formally authorise the work to be undertaken and then perform the authorised work. 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. Each 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 measured and aggregated.

8 Accumulate and Report Performance Data

Record and accumulate schedule progress, earned value and actual cost for each element on a consistent and periodic basis. The Planned Value, Earned Value, Actual Costs, and Estimate to Complete are calculated and logically summarised through the project decomposition (WBS) to properly represent the status of both 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).

In addition, all costs actually incurred in the performance of the work (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 Performance

Identify and analyse variances from the Performance Management 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.

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).

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[6].

10 Management Action

Take management action to compensate for past deviations or to rectify projected deviations from the Performance Management 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 Management Baseline can originate either internally through the identification of unforeseen scope changes or resource requirements or where changes have been directed by other stakeholders. Where there have been changes to the project, it will be

[6] The various ***formulae used to calculate the EV metrics*** are details below, and in: https://mosaicprojects.com.au/WhitePapers/WP1081_Earned_Value.pdf

necessary to replan certain elements of the work. Due to the importance of maintaining a valid baseline for Management, replanning should be accomplished:

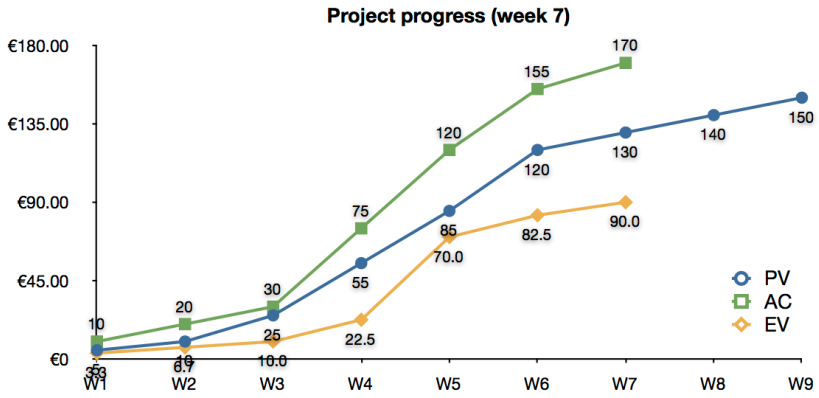
- With proper authority
- In a systematic and timely manner
- Should be carefully controlled, and
- Adequately and visibly documented.

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

Maintenance of the Management 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 Management 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 and a defined set of formulae[7].



	Budget at Completion	Planned Value	Actual Costs	Earned Value	Schedule Variance	Cost Variance
A	$1,000	$1,000	$1,200	$ 1,000	$0	<$200>
B	$ 500	$ 500	$ 400	$ 400	<$100>	$0
C	$2,000	$1,500	$1,200	$1,000	<$500>	<$200>
D	$4,000	$2,000	$2,200	$2,500	$500	$300
E	$1,000	$ 0	$ 100	$ 100	$100	$0
Total	$8,500	$5,000	$5,100	$5,000	$0	<$100>

[7] For more on ***Earned Value Formulae*** see: https://mosaicprojects.com.au/WhitePapers/WP1081_Earned_Value.pdf

Basic EV Data

Planned Value (PV)	Otherwise called Planned Budget or (now outdated term) Budgeted Cost of Work Scheduled (BCWS). The authorised budget for the project work scheduled. Distributed over time (cumulative) using the Managements 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.
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 $IEAC = ACWP + \frac{(BAC-EV)}{CPI} = \frac{BAC}{CPI}$ Assuming future cost performance will be influenced by factors of 80% past cost and 20% past schedule performance $IEAC = ACWP + \frac{(BAC - EV)}{0.8 \times CPI + 0.2 \times SPI}$ Assuming future cost performance will be influenced by the last 3 months cost performance $IEAC = ACWP + \frac{3 \times (BAC - BCWP)}{CPI1 + CPI2 + CPI3}$

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

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

Simply repricing (Re-estimating) 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).

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(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. Either an update (or status) of the project schedule is necessary to relate this to a calendar, or the use of Earned Schedule[8] to predict the overall delay is required.

Understanding the nature of the work causing the SV is important. For example, a negative SV due to nonreceipt of material might be recovered

[8] For more on ***Earned Schedule*** see: https://www.mosaicprojects.com.au/Mag_Articles/N003_Earned_Schedule.pdf

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.

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

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).

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

Cost Variance % (CV%)

The Cost Variance expressed as a percentage of Earned Value.

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

Schedule Variance % (SV%)

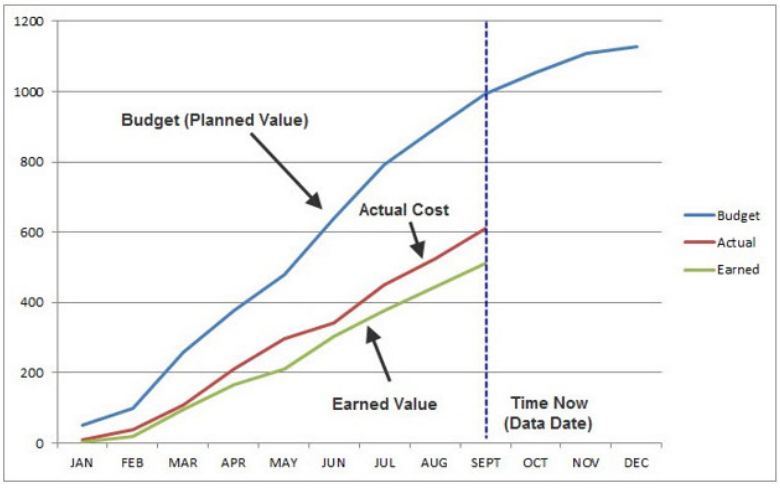
The Schedule Variance expressed as a percentage of Planned Value.

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

Interpreting EV Data

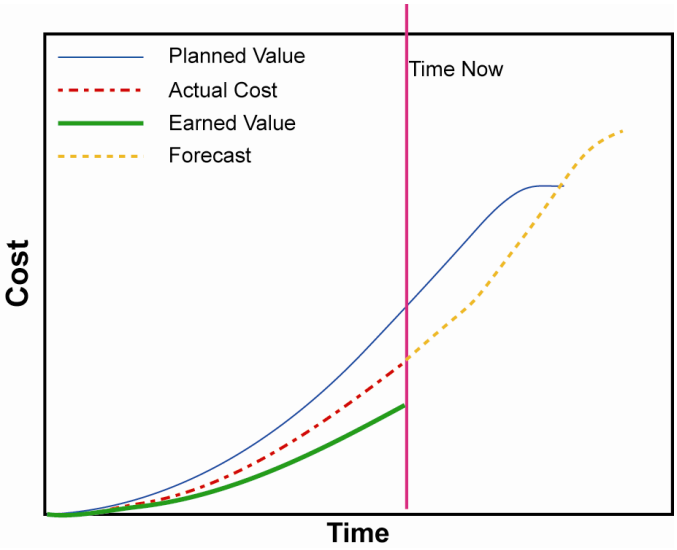
Note - EV does not have to be measured in $

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. A vertical dashed line positioned at the date of the last update separates actual data input by the project team from forecast data.



Overall Project Completion Data

The vertical line positioned at the date of the last update separates actual data input by the project team from forecast data. The blue line plots the original planned expenditure on the project from its start to its original projected end date (Planned Value or PV). The red line plots the actual expenditure to date, and the yellow line the expenditure required to complete the unfinished portion of the project. Traditional Earned Value can predict the cost overrun (or underrun), the forecast delay has to be based on information contained in the schedule, of from Earned Schedule calculations.

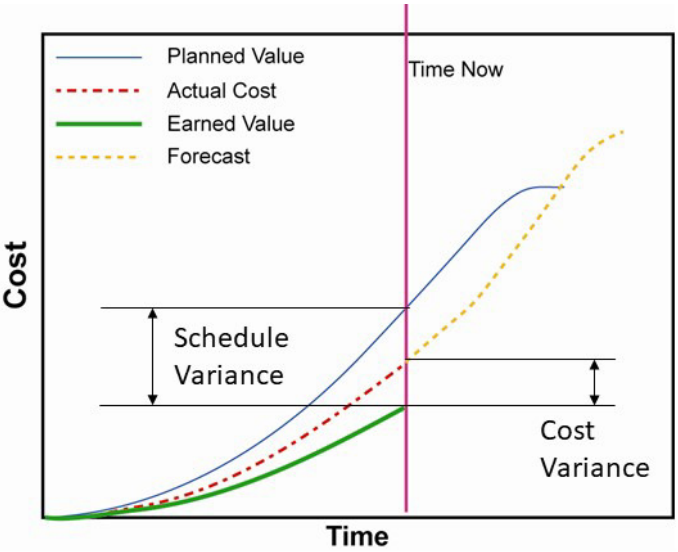


The horizontal difference between the end of the blue line and the end of the yellow line is the slippage (gain or loss) between the current expected completion date for the project and the original planned date.

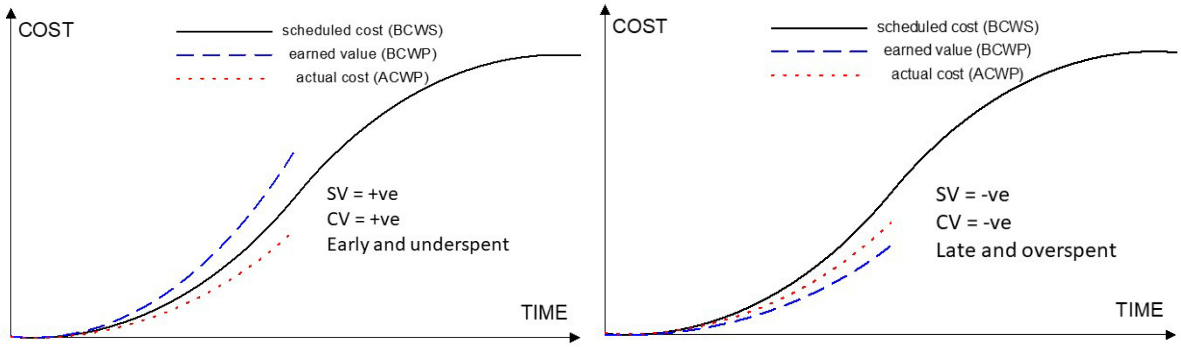
Current Performance Data

Information at 'Time Now' compares the amount of work accomplished compared to the plan (SV or SPI) and the cost of completing that work compared to the estimate (CV or CPI)

These two variances result in nine possible scenarios with varying degrees of magnitude in both dimensions. The 'ahead of schedule, under budget' and 'behind schedule, over budget' options are shown below.

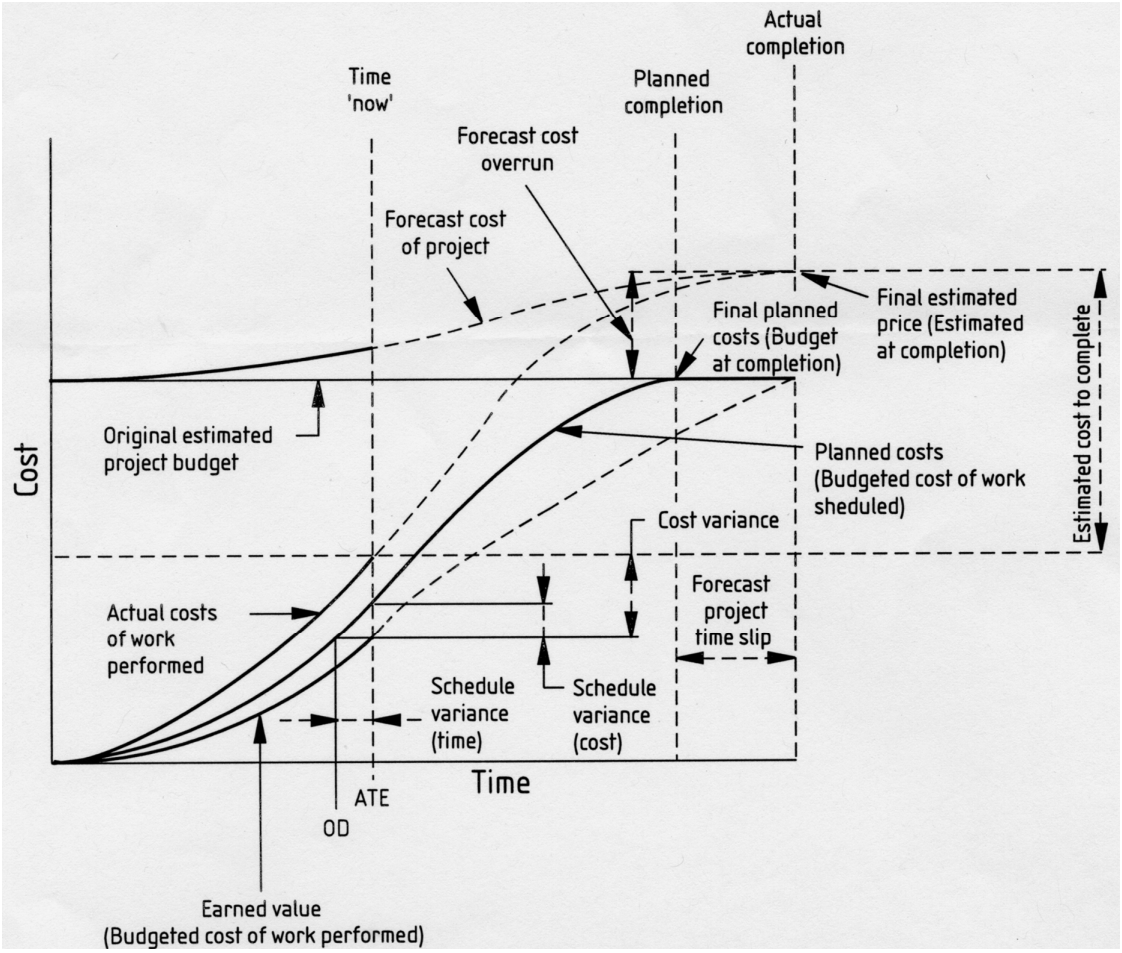


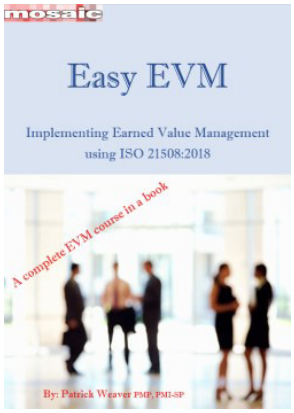
Performance Measures		Schedule		
		SV > 0 & SPI > 1.0	SV = 0 & SPI = 1.0	SV < 0 & SPI < 1.0
Cost	CV > 0 & CPI > 1.0	Ahead of Schedule Under Budget	On Schedule Under Budget	Behind Schedule Under Budget
	CV = 0 & CPI = 1.0	Ahead of Schedule On Budget	On Schedule On Budget	Behind Schedule On Budget
	CV < 0 & CPI < 1.0	Ahead of Schedule Over Budget	On Schedule Over Budget	Behind Schedule Over Budget



Note: in both of these graphs, the 'actual cost' is about the same, what differs is the amount of work accomplished as measured by the Earned Value (blue line in these charts).

The complete picture is a comprehensive status of the project. Research suggests the cost performance information is more reliable than any other predictive method from around the 20% complete stage of the project, improving in accuracy as more work is accomplished. Using Earned Schedule, a similar level of accuracy is derived for the forecast completion date.





Easy EVM - Implementing Earned Value Management using ISO 21508:2018

Easy EVM is a self-paced course-in-a-book, supported by Mosaic Project Services Pty Ltd. The purpose of this 'course-in-a-book' is to provide practical guidance to people, and organizations, involved in either implementing an earned value management system, or using information created by an earned value management system. It provides guidance on concepts, responsibilities, integration, and processes, for the implementation and use of earned value management based on ISO 21508: *Earned Value Management in Project and Programme Management*. The book is divided into five sections, each section includes guidance on an aspect of EVM, references, and a set of 20 questions; with the answers in Section 6.

Open the Book2Look preview to see the full table of contents, sample pages, and sample questions & answers. The free preview is available at: https://www.book2look.com/book/vwFQYiaJkd

For more information see: https://mosaicprojects.com.au/shop-easy-evm.php

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