

Earned Value Formulae

This White Paper focuses on the basic values and formulae used in Earned Value calculations. Additional EV resources are available from <http://www.mosaicprojects.com.au/Techniques.html#EarnedValue>

This paper uses the various EV acronyms as follows:

- EV = Calculated value (see below)
- EVM = Earned Value Management (what people do)
- EVMS = Earned Value Management System (the tools and processes used to perform EVM)

Earned Value Management is a performance management technique that typically uses monetary value as a metric to allow the inclusion of direct labour, material supplies and sub-contractors in a single system. However, the value unit does not have to be money, labour hours or any other convenient metric maybe used. Importantly, EVM should not be confused with cost management or financial control, these are quite different processes.

The keys to an effective EVMS are:

- The project scope divided into a practical WBS to generate meaningful work packages¹.
- The use of appropriate standards to develop an efficient EVMS².
- The use of an appropriate metric for performance measurement - the default is currency (eg, \$ or £) however other metrics may be more relevant such as: Hours of effort for an internal project, or 'story points' / 'function points' for an Agile³ project.
- A coherent set of measurements based on realistic data.
- The willingness of management to make use of the information in the management of the project.

The Earned Value Building Blocks:

Planned Costs

Budget At Completion = BAC

The starting point for establishing the project budget is the 'contract sale price' for the project's deliverables paid by the client. In commercial contracts this includes the performing organisation's profit margin and any other fees and charges the organisation will recover from the client. The **project budget** is the expected total cost of doing the work of the project, excluding these profits, etc.

The **project budget** is the total allowance for the costs of a project including the **Performance Management Baseline (PMB)** - the defined costs of the work; plus any **management reserves (MR)** held outside of the project budget to cover the costs of unforeseen risk events (unknown-unknowns). Management reserves are controlled by the organisation, the PMB is controlled by the project manager.

Earned Value Management focuses on managing the PMB component of the overall project cost. Management Reserves (MR) are the contingencies created to cover unforeseen risk events and will only be

¹ For more on **WBS** see: http://www.mosaicprojects.com.au/WhitePapers/WP1011_WBS.pdf

² Practical **EVM Standards** include:

- AS4817, Project Performance Management using Earned Value.
- PMI *Practice Standard for Earned Value Management*, see: <http://www.mosaicprojects.com.au/Techniques.html#EarnedValue>
- APM (UK) Guidelines for Earned Value Management.

³ For more on **managing Agile projects** see:

- http://www.mosaicprojects.com.au/PDF_Papers/P109_Thoughts_on_Agile.pdf



transferred into the baseline if an unexpected risk event occurs and is at the discretion of the project sponsor or authorised senior managers.

CONTRACT PRICE		
PROJECT BUDGET		PROFIT/ MARGIN
PERFORMANCE MEASUREMENT BASELINE		MR
CONTROL ACCOUNT (DISTRIBUTED BUDGET)		UNDISTRIBUTED BUDGET
WORK PACKAGES	PLANNING PACKAGES	
ACTIVITIES		

The PMB is the authorised or ‘planned’ cost of the work; which in Earned Value terminology is also called the **Budget At Completion (BAC)**.

The PMB and BAC are closely related, 100% of the PMB is the same as the BAC (budget). This includes the cost of completing the work (allocated to control accounts and work/planning packages)⁴, any undistributed budget and contingency reserves.

Apart from the earliest stages of a project, there should be no **undistributed budget**; all of the budget should be allocated to planning packages or work packages as soon as possible.

Contingency reserves are held within the PMB for accepted, but currently unallocated risk events. The reserves are generally not included in a work package because the cost consequences of the identified risk have not occurred ‘at this point in time’ and may never occur - risks are uncertain events that may, or may not happen. When a defined risk event occurs, an appropriate amount of the reserves is transferred to the affected work packages.

A more detailed break-up of the project costs with accountabilities is:

Funding			<u>Accountability</u>	
Cost Performance Measurement Baseline (BAC)		Management Reserve	Business Sponsor	
WBS Control Account		Undistributed Budget	Contingency	Project Manager
Discrete Work Packages	Level of Effort Tasks	Planning Packages		

Level of effort (LoE) tasks are work packages that have no productive measures allocated (eg, safety attendants). The costs are simply distributed over the expected time the work will occur. Most authorities require LoE tasks to be kept to a practical minimum.

⁴ For more on **work packages, planning packages and control accounts** see: http://www.mosaicprojects.com.au/WhitePapers/WP1011_WBS.pdf



Planned Value = PV (also referenced as: **BCWS** – Budgeted Cost of Work Scheduled⁵)

PV is the sum of the authorised budget assigned to a specific elements of the work (usually work packages), within a defined time period. When the budget is fully assigned, the PV for the project equals the BAC.

Measuring Work Performed

Earned Value = EV (also referenced as: **BCWP** – Budgeted Cost of Work Performed)

EV is the measure of the work actually performed, expresses in terms of the budget authorised for that work. If a work package has a planned value (PV) of \$8,000 and is 50% complete the ‘value’ of the work accomplished (ie, the value earned, or EV) is 50% of \$8,000 = \$4,000. When the work is 100% complete, the EV becomes \$8,000. When all of the work on the project is complete, the Earned Value = Planned Value = BAC: all three of these values are derived from the authorised budget for the work.

Actual Cost = AC (also referenced as: **ACWP** – Actual Cost of Work Performed)

AC is the actual cost incurred in performing the work. Whilst it is to be hoped the actual costs will be similar to, or less than the planned costs (the budget), AC is a fact derived from the project administrative systems (usually either the finance system or the timesheet system). The difficult in apply in EV is determining the AC of work within a few days of it being completed; finance systems can be up to 6 weeks late in recording and allocating costs to project line items.

Aligning PV, EV and AC

For the EVMS to report accurately it is vital that the three components, EV, PV and AC are assessed on the same basis and at the same date. The values can be cumulative to date for the whole project, for a specific time period (eg, a month) or for a specific work element.

EV Formulae

The four components outlined above, BAC, PV, EV and AC, allow current and future performance to be assessed. The formulae below are the core elements of EV, most standards include more sophisticated measures in addition to these. The formula can be used for the whole of the work to date (cumulative), for a set time period or for a defined element of the work (eg, a work package).

Current performance

Cost Performance CV and CPI

The calculation of how efficiently the project is acquiring and using resources to accomplish the work.

- **Cost Variance = CV** the difference between the value of the work accomplished (EV) and the cost of accomplishing the work (AC)
 - **CV = EV – AC**
 - A negative value means the work is costing more than budgeted (bad news)
 - A positive value means the work is costing less than budgeted (good news)

⁵ The four letter acronyms are still used by the USA DoD and in the UK standards. These have been updated to the two letter acronyms used in this paper in the *PMBOK® Guide*, the Australian, and most other standards. This paper will use two letter acronyms throughout.

- **Cost Performance Index = CPI** a ratio of the difference between the value of the work accomplished (EV) and the cost of accomplishing the work (AC)
 - **CPI = EV / AC** (Earned Value divided by Actual Cost)
 - A CPI of 1 means the cost of the work is exactly the same as the budget for the work.
 - A CPI of less than 1 (ie, 0.99 or less) means the work is costing more than budgeted (bad news)
 - A CPI greater than 1 (ie, 1.01 or more) means the work is costing less than budgeted (good news)

Schedule Performance SV and SPI

The calculation of how effectively the project is using resources to accomplish amount of work planned within a defined time period.

- **Schedule Variance = SV** the difference between the amount of work actually accomplished (EV) and the amount of work planned to be accomplished (PV) in a defined period, or cumulative to date
 - **SV = EV – PV**
 - A negative value means less work is being accomplished than planned (bad news)
 - A positive value means more work is being accomplished than planned (good news)
- **Schedule Performance Index = SPI** a ratio of the difference between the value of the work actually accomplished (EV) and the value of work planned to be accomplished in the period (PV)
 - **SPI = EV / PV** (Earned Value divided by Planned Value)
 - A SPI of 1 means the amount of work accomplished is exactly the same as the amount of work planned to be accomplished.
 - A SPI of less than 1 (ie, 0.99 or less) means less work is being accomplished than planned (bad news)
 - A SPI greater than 1 (ie, 1.01 or more) means more work is being accomplished than planned (good news)
- **Percent Complete** the amount of work completed to date expressed as a percentage.
 - **% complete = (EV / BAC) * 100**
(Earned Value divided by the approved budget expressed as a percentage)

Predicted future performance - Cost

Earned Value can be used to predict future cost performance.

Estimate At Completion EAC (or Independent Estimate At Completion IEAC)

The calculation the expected final **cost** of the project. There are many different options for calculating EAC, the simplest are:

- **EAC #1** Scale the overall cost performance based on actual performance to date
 - **EAC = BAC / CPI** (the Budget At Completion divided by CPI)
 - This is the simplest option, only useful in PMI examinations. The overall budget is scaled in proportion to the cost performance to date.



- **EAC #2** Scale future cost performance based on actual performance to date
 - **EAC = AC + [(BAC - EV) / CPI]** (Actual Cost + the remaining budget divided by CPI)
 - The total estimate is the actual cost to date plus the remaining budget scaled in proportion to the cost performance to date. If there has been no change in the project, this is identical to the formula above⁶, however, if the project has been rebaselined, you need this formula.
 - This tends to be the lowest likely cost outcome if the project is over budget.

- **EAC #3** Assume future performance will be in alignment with the original budget.
 - **EAC = AC + (BAC - EV)** (Actual Cost + the remaining budget)
 - The total estimate is the actual cost to date plus the remaining budget. This formula is used early in every project to avoid major fluctuations (typically through to around the 15% to 20% stage) and in any circumstances where current performance has no relevance to future performance.

- **EAC #4** Assume future performance will be a combination of current cost and schedule performance.
 - **EAC = AC + [(BAC - EV) / (CPI x SPI)]** (Actual Cost + the remaining budget scaled by the combination of CPI and SPI - also called the 'critical ratio')
 - Critical Ratio: $CR = CPI \times SPI$ (see Indices section below)
 - The total estimate is the actual cost to date plus the remaining budget scaled in proportion to the cost performance to date, adjusted by SPI. This option is preferred by some authorities and recognises that schedule performance has an impact on cost performance.
 - This tends to be the highest likely cost outcome if the project is over budget and over time.

Estimate To Complete ETC

The calculation the remaining costs still to be expended to complete the project.

- **ETC = EAC - AC** (the total expected cost of the project less the actual costs expended to date)
 - This is the amount of money needed by the project to complete the work.

Variance At Completion VAC

The variance of total approved budget for the work and expected cost.

- **VAC = BAC - EAC** (the total budget for the project less the estimated total cost)
 - This is the predicted Cost Variance at the completion of the work.
- **Variance at Completion Percentage (VAC%)** $VAC\% = VAC / BAC * 100\%$

⁶ Based on the set numbers that can be included in a PMP question, EAC#1 and EAC#2 are the same.

The key formulae are **EAC = AC + ((BAC - EV) / CPI)** and **CPI = EV / AC** the proof is:

Change AC to a factor of EV; If $CPI = EV / AC$, then $AC = EV / CPI$

Substituting this formula for AC in the equation EAC#2, where **EAC = AC + ((BAC - EV) / CPI)** gives....

$EAC = EV / CPI + ((BAC - EV) / CPI)$ writing this as a single statement: $EAC = \frac{EV + BAC - EV}{CPI}$

Crossing out the positive and negative EVs gives **EAC = $\frac{BAC}{CPI}$** **This is EAC#1, but: make sure you remember the other options for the exam.**



Predicted future performance - time

Traditional Earned Value can only be used to predict future cost performance. To predict future schedule performance requires the use of other techniques including Earned Schedule⁷.

Expected At Completion - Time (EAC(t)), is equal to:

EAC(t) = AT + PDWR when:

- AT: The actual time moment (i.e. today)
- PDWR: Planned Duration of Work Remaining

The way the PDWR is calculated depends on the methodology used:

Schedule Performance Index

The EAC(t) based on the SPI is known to be inaccurate in the later half of a project due to the inevitability of SPI eventually returning to 1 at project completion.

Using the schedule

Using the remaining duration calculated by updating a CPM schedule is typically optimistic. Without modification CPM makes no allowance for the performance to date⁸.

Earned Duration

Attempts to adjust the predicted completion date using a range of 'Performance Factors' (PF).

$$\text{EAC}(t)_{ED} = \text{AT} + (\max(\text{PD}, \text{AT}) - \text{ED}) / \text{PF}$$

Where: PD = Planned Duration and ED = Earned duration

Earned duration is the time at which the current Earned Value was planned to be achieved.

The use of max (PD, AT) can be explained as follows:

- Project progress is still before the planned completion date: if AT < PD then PD is used
- Project progress is already late: if AT > PD then AT is used

The PF can be 1 or SPI or SPI * CPI. This method is more accurate than the other traditional EV options but not as effective as Earned Schedule in predicting the project completion date.

Earned Schedule (ES)

Earned Schedule uses the same data as Earned Value and the concept of Earned Duration (called Earned Schedule in this methodology) but uses time based formula similar to the EAC cost calculations to predict project completion. Studies have consistently shown ES to be as reliable in predicting project completion as traditional EV is in predicting the final project cost. ES also performs more accurately than any of the other time prediction options. For more on ES see: <http://www.earnedschedule.com/>

Using Earned Value to manage projects

The data derived from the EV formulae in this paper are of no use unless it is used as a management tool for informed decision making. There are nine potential outcomes from the calculations:

⁷ For more on *Earned Schedule* see: http://www.mosaicprojects.com.au/Mag_Articles/N003_Earned_Schedule.pdf

⁸ See *Why Critical Path Scheduling (CPM) is Wildly Optimistic*: http://www.mosaicprojects.com.au/PDF_Papers/P117_Why_Critical_Path_Scheduling_is_Wildly_Optimistic.pdf



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

The managers responsible for each section of the work (Work Package or Control Account) should be required to consider the following key questions⁹ and report on them if the measured variance is outside of acceptable limits:

- Past Performance
 - Are we on schedule? (SV)
 - Are we on cost? (CV)
 - What are the significant variances?
 - Who is responsible?
 - What is the trend to date?
 - What risks have been reduced or added?
- Future Performance
 - What is the "to go" plan?
 - How is it resourced?
 - When will we finish?
 - What will it cost in the end?
 - How can we control the trend?
 - How can we adjust for risk?

The answers to these questions come from the EVMS. By reflecting on the answer to each, the project team can focus on "managing the work" **using** the numbers and not just reporting the numbers.

Performance Indices

There are a number of performance indices in common use – most are of limited value. The most common are:

TCPI – To Complete Performance Index

This option is preferred by PMI and is the most useful. TCPI measures the degree of change needed to achieve a project objective. It is a measure of the cost performance that must be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the

⁹ Source, Glen B. Alleman, Herding Cats blog: http://herdingcats.typepad.com/my_weblog/



outstanding work to the budget available. The target is either BAC or if this is unachievable EAC – an increase in performance of more than 10% is generally considered unachievable (TCPI = 1.1 or more). The TCPI compares the work remaining (defined as the BAC minus the EV) divided by the funds remaining (which can be either the BAC minus the AC, or the EAC minus the AC)¹⁰.

Equation for the TCPI based on the BAC:

$$\text{TCPI} = \frac{(\text{BAC} - \text{EV})}{(\text{BAC} - \text{AC})}$$

Equation for the TCPI based on the EAC:

$$\text{TCPI} = \frac{(\text{BAC} - \text{EV})}{(\text{EAC} - \text{AC})}$$

Schedule Index (SI)

The concept of Schedule Index (SI) is similar to the Earned Schedule concept of SPI(t) - Schedule Performance Index (time). SI shows how much current progress is ahead/behind the baseline. In this example SI is based purely on the critical path and the effect of progress to date on the scheduled completion of the project, however, there are numerous other ways to calculate SI.

$$\frac{\text{Project duration to date (plus time ahead or minus time behind)}}{\text{Project duration to date}}$$

SI typically does not consider performance aspects other than project gain or slippage.

Note: SPI(t) considers the overall time achieved from a 'value' perspective across all activities. Traditional SPI considers the value of work accomplished from a monetary perspective only, without relating it to time.

Critical Ratio (CR) or Critical Index (CI)

CR is calculated as CPI x SPI. Whilst potentially useful in predicting the maximum likely EAC if the project is over budget and behind schedule, the problem with this ratio as a reporting tool is that it hides important information in a rounded up number:

SPI = 0.99, CPI = 0.65 (ie, the project is basically on schedule but overrunning cost), CR = 0.643

SPI = 0.58, CPI = 1.109 (ie, the project is profitable by seriously behind schedule), CR = 0.643

The CR is effectively the same for two very different scenarios.

Planned PCT

The percent of budget expected to have been expended as of the most recent reporting period. It is calculated by dividing the cumulative BAC (most recent reporting period) by total budget: (BACcum / BACtotal) / 100. For example...if you have a total budget of \$5,000 and your BACcum as of your most recent reporting period is \$200, your Planned PCT will be 4%. In most cases BACcum = PVcum.

¹⁰ A detailed analysis of the **TCPI and its application**, see:
http://www.mosaicprojects.com.au/WhitePapers/WP1097_TCPI_in_EVM.pdf



This White Paper is part of Mosaic's ***Project Knowledge Index*** to view and download a wide range of published papers and articles see: http://www.mosaicprojects.com.au/PM-Knowledge_Index.html

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For more on project controls and scheduling see: <http://www.mosaicprojects.com.au/Planning.html>

