# EVM.03

# The ABCs of Earned Value Application

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Completing a project on time, on budget and safely is a fundamental management expectation. With a few exceptions, most project durations range from twelve to thirty months from initiation to close-out. During such a long project life cycle, how can the project team gain confidence in achieving cost and schedule expectations? What tools are available to provide early warnings and make timely corrective actions? The earned value management system (EVMS) is a simple and powerful tool to enable the project team to execute the project with a high degree of confidence.

Industrial engineers first applied the "earned value" concept to measure the performance on the factory floor in the 1800's. The US government has also applied this concept since the 1960s. However, the earned value remains one of the most under-used, yet effective cost management tools available for performance measurement [4]. The author believes it is caused by the lack of understanding for earned value basics and its potential benefits, as well as unnecessary complex reports and interpretations. This paper presents a concise and easily understood earned value concept suitable for new users, and serves as a refresher for experienced users. Reference articles are also included for advanced users.

### WHAT IS AN EARNED VALUE?

In its most basic form, earned value answers the question, "What did I receive for what I spent?" [12] In a broad sense, cost may include any investment of resources in strategic assets including time, monetary, human, and physical resources [9]. The two most common denominators used in earned value system are monetary ($) and human resources (work hours). Other quantities may be used to measure performance. However, they are converted to either $ or work hour (WH) eventually in the earned value system for the ease of analysis.

### TRADITIONAL COST MANAGEMENT VERSUS EARNED VALUE

Traditional cost management uses a two-variable approach to relate the "actual cost" to the "planned cost." Since the actual performance efficiency is not as precise as the initial assumption used in the project planning phase, the actual cost incurred is not a true reflection of the actual accomplishment.

For example, after spending 50 percent of the project budget, is the project at 50 percent complete?

Therefore, a third variable called "earned value" is needed to measure actual accomplishment. Figure 1 depicts the variance comparison. The earned value system reduces subjectivity, and provides a more objective performance measurement. The basic concept of establishing and maintaining a plan against which to measure actual accomplishment is one of the most fundamental management principles. Earned value is a practical tool to apply such principle.

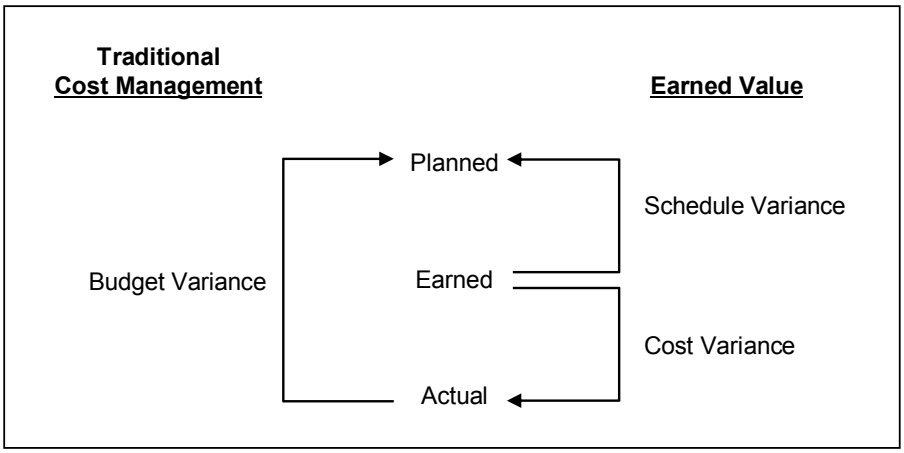


**Figure 1 – Traditional Cost Management vs. Earned Value**

## BASICS OF EARNED VALUE

### Three Basic Variables

Only three basic variables are used in earned value system. All other variances, performance indices and forecast costs are derived from these three basic variables. For the ease of application, variables are referred to as "planned", "earned" and "actual." Table 1 provides synonymous terms used in the earned value management system (EVMS) and cost/schedule control system criteria (C/SCSC). These three variables provide a wealth of data reflecting the true health of projects.

| Planned | Earned | Actual |
|---|---|---|
| PV | EV | AC |
| Planned Value | Earned Value | Actual Costs |
| BCWS | BCWP | ACWP |
| Budgeted Costs Work Scheduled | Budgeted Costs Work Performed | Actual Costs Work Performed |
| Baseline/planned costs for work scheduled to be finished | Costs of work finished expressed in budget term | Costs incurred on work you have already finished |

**Table 1 – Synonymous Terms Used in Earned Value**

### Prerequisites to Applying the EVMS

The EVMS incorporates organized components of the project's schedule, project estimate and scope of work into a process that enables a more reliable determination of the project's forecasted costs [13]. Embracing the following prerequisites during the project planning phase will establish a solid foundation to implement a credible EVMS [8]. Prerequisites include the following:

- Convert scope of work into a work breakdown structure (WBS).
- Each WBS element becomes a work package that describes a measurable product, action or service.
- Develop a time-phased schedule of values associated with WBS.
- Assign responsibility for each control account.
- Determine the appropriate progress measurement method.
- Establish a consistent practice to collect actual costs ($ or WH).
- Set a threshold level of performance variance to trigger corrective action.

### EVMS Process

The EVMS is a continuous project control/management process. It begins with the tracking of the three basic variables (PV, EV, AC). From these variables, analyses are performed to determine the current and cumulative variances or performance indices. The "estimate to complete" (ETC) and "estimate at complete" (EAC) are forecasted based on the analysis data. Timely corrective actions are taken to mitigate project risks. Figure 2 is a simplified EVMS process.

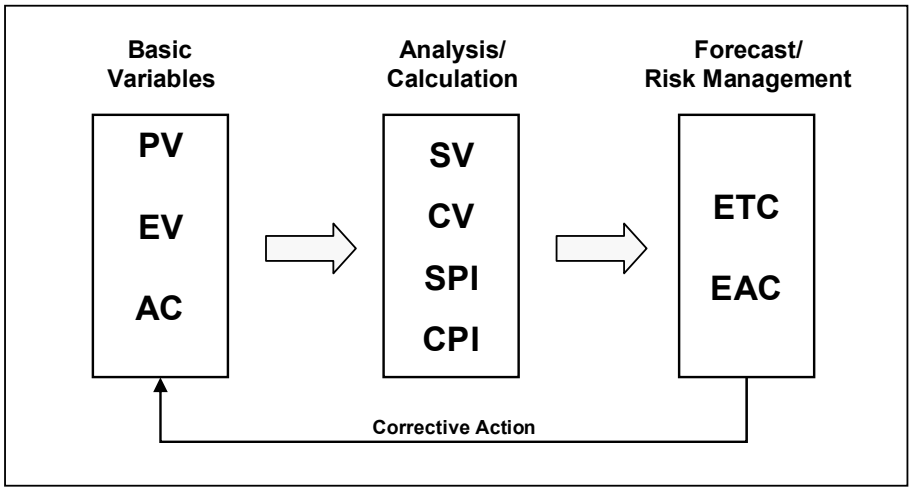


**Figure 2 – Simplified EVMS Process**

**Earned Value Analysis**

The three basic variables (PV, EV, AC) must be in the same unit of either $ or WH. Even if the tracking is based on the physical quantity installed (i.e., linear meter of pipe installed), ultimately such quantity would have to be converted to either $ or WH to facilitate earned value analysis. Engineering progress is linked to the deliverable packages, which are closely related to the engineering effort measured in WH. Many projects select WH as the basis to measure engineering earned value [2]. The selection of $ vs. WH is also influenced by the data available from the chosen contract style (i.e., lump sum vs. cost reimbursable). It is essential to determine the project preferred contract style, and select the appropriate unit ($ or WH) in EVMS.

The analysis begins with the determination of earned value of the current period and project to date. Earned value is the pivotal variable. The analysis ends with comparisons of earned value to either planned value or actual cost.

**How is Performance Variance Used?**

Variance is used to determine the **MAGNITUDE** of deviation for a given project. For example, subtracting "planned" from "earned" yield a schedule variance:

SV (Schedule Variance) = Earned–Planned = EV–PV

A positive SV indicates the work is accomplished more favorably than the original plan. However, this does not always imply the project is ahead of schedule. When EVMS is combined with the critical path method (CPM) schedule, the true project schedule status is revealed. A project could devote excessive resources to accomplish non-critical path activities with a resultant positive SV while critical path activities fall behind unknowingly.

The cost variance is determined by subtracting "actual" from the "earned":

CV (Cost Variance) = Earned–Actual = EV–AC

A positive CV indicates the work is accomplished more efficiently than the estimated efficiency in the plan. A large negative CV signals a project overrun. Cost overruns are generally more serious than being late to the planned schedule, only because the schedule might be recovered using crashing technique. However, the cost overruns are rarely (if ever) fully recovered. [5]

Both schedule and cost variances are meaningful to a given project since they reflect the deviation magnitude applicable to that project only. They are not suitable for comparing against the performance of another project.

**Performance Index Calculation**

The performance index is simply the ratio of earned to either planned or actual. It is dimensionless.

$$\text{SPI (Schedule Performance Index)} = \frac{\text{Earned}}{\text{Planned}} = \frac{\text{EV}}{\text{PV}}$$

$$\text{CPI (Cost Performance Index)} = \frac{\text{Earned}}{\text{Actual}} = \frac{\text{EV}}{\text{AC}}$$

A ratio over 1 indicates favorable progress. However, SPI >1 does not automatically imply ahead of schedule. A CPM schedule is required to validate the true schedule performance as discussed in the performance variance section. A CPI of 0.9 indicates that the project is receiving $0.9 of value for every $1 spent.

Performance indices can be calculated for the current period (i.e., month) and project-to-date (cumulative). Plotting these performance indices enables the trending analysis. Refer to figure 3 for an example.

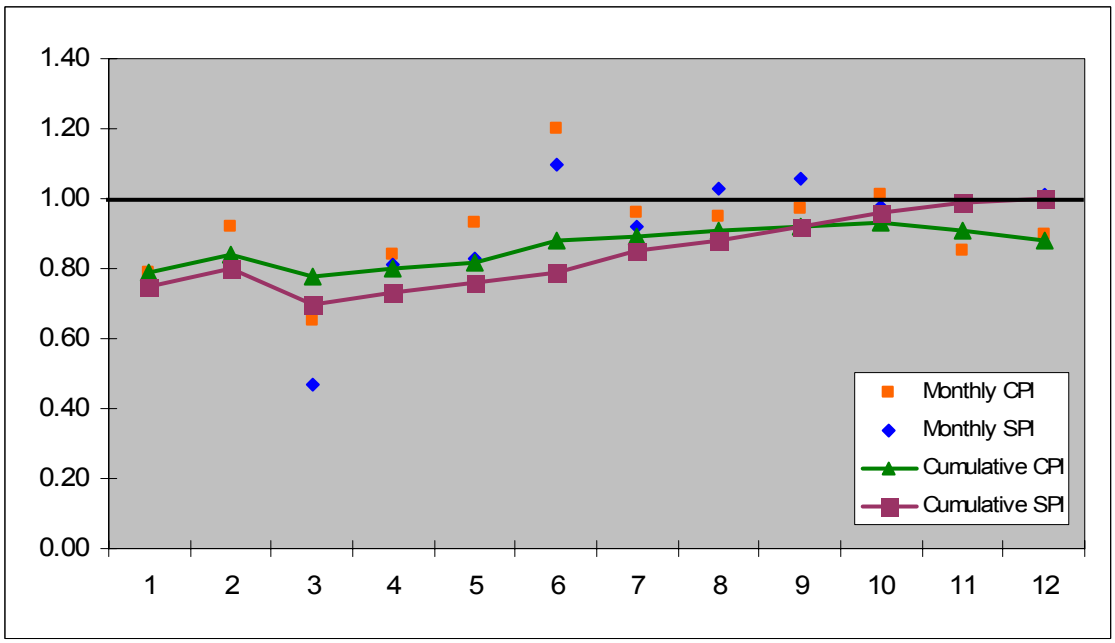


**Figure 3 – Current and Cumulative Performance Indices**

The significance of the CPI metric is that it has been empirically proven (with over 700 Department of Defense projects studied) to stabilize at the 20 percent completion point of a project. Also, the CPI metric becomes progressively more stable as the project continues toward 100 percent completion. The CPI can be used to forecast the final project costs as early as 20 percent into the project. [5]

**Using Performance Indices to Forecast Costs and Manage Risks**

EVMS does not end at the determination of performance indices. Projects sometimes fail to take the full advantage of the valuable insight revealed by these indices to forecast the final project costs. Performance indices are simple and effective metrics to forecast estimate to completion (ETC) for the remaining work as well as estimate at completion (EAC). The EAC is compared with budget at completion (BAC, the total planned value) to assess the project risk and develop a risk mitigation plan, if required.

The actual project final cost is not known until the project is actually completed. EAC should not be a single point estimate. A possible range of EAC is more realistic to guide the project team to manage project risk. A practical approach to estimate EAC should include future risk analysis regardless of the validity of current baseline or performance indices [14].

For example, assume the project's original budget is $1,000,000 (BAC, budget at completion). At 40 percent project completion, the cumulative SPI and CPI are 0.92 and 0.8 respectively. The forecasted EAC range can therefore be determined by:

$$\text{Low EAC} = \frac{\text{BAC}}{\text{CPI}} = \frac{\$1{,}000{,}000}{0.8} = \$1{,}250{,}000$$

$$\text{High EAC} = \frac{\text{BAC}}{\text{CPI x SPI}} = \frac{\$1{,}000{,}000}{0.8 \text{ x } 0.92} = \$1{,}358{,}695$$

The most likely EAC would be between $1,250,000 and $1,358,695. This forecast process is repeated at each period with each set of updated CPI and SPI metrics. Such early warning provides effective communication to stakeholders, and enables the project team to implement timely risk mitigation action.

Earned value analysis is a backward-looking tool based on past performance [7]. When combined with trending analysis and above EAC forecast, it becomes a valuable forward-looking tool as well. The estimate to completion (ETC) for the remaining work requires a thorough assessment of future cost and schedule performance. To apply this, let's use the same example above with the cumulative earned and actual at $368,000 and $460,000 respectively, vs. $400,000 planned at 40 percent project complete. The range of ETC can therefore be calculated for:

$$\text{Low ETC} = \frac{\text{BAC} - \text{Earned}}{\text{CPI}} = \frac{\$1{,}000{,}000 - \$368{,}000}{0.8} = \$790{,}000$$

$$\text{High ETC} = \frac{\text{BAC} - \text{Earned}}{\text{CPI x SPI}} = \frac{\$1{,}000{,}000 - \$368{,}000}{0.8 \text{ x } 0.92} = \$858{,}695$$

As the project progresses toward the completion, the efficiency to complete the last 10 percent of work generally decreases since the workforce is no longer in the high volume and peak productivity period. It is unrealistic to expect the remaining work could be accomplished at the original cost and schedule efficiency with a 1.0 performance index. The most likely ETC will fall between $790,000 and $858,695. The EAC can also be determined from:

EAC = Actual + ETC = Total Cumulative Cost to Date + ETC

## PROGRESS MEASUREMENT

Earned value is the pivotal variable in EVMS. The progress measurement is best determined by objective instead of subjective assessment. The determination of percent complete is a complex matter, often misunderstood by both project managers and project control engineers [11]. Chapter 14 of the AACE International **Skills & Knowledge of Cost Engineering** 5th edition defines six different methods to measure progress [9]. These are:

- unit completed;
- incremental milestone;
- start/finish;
- supervisor opinion;
- cost ratio; and
- weighted or equivalent units.

Only three of the most commonly used methods are briefly discussed in this paper. The unit completed method is widely used on repeated production of easily measured piece work, when each piece requires approximately the same level of effort. Construction progress such as lineal meter pipe installed is a typical application.

The incremental milestone method is applicable to any control account with tasks that must be completed in sequence. For example, developing an engineering specification and procurement package includes typical tasks as shown in table 2.

| Task | Incremental Progress | Cumulative Progress |
|---|---|---|
| Basic Spec Established | 10% | 10% |
| Input Data Collected | 10% | 20% |
| Calculation Executed | 20% | 40% |
| Owner's Approval | 40% | 80% |
| Issued for Bid | 15% | 95% |
| Issued for Purchase | 5% | 100% |

**Table 2 – Engineering Specification/Procurement Progress Measurement**

The cost ratio method is applicable to tasks that involve a long period of time, or are continuous during the life of a project with a steady level of effort. These tasks are usually estimated and budgeted on bulk allocations of dollars and work hours rather than on the basis of quantifier production. Soft skill tasks such as project management, quality assurance, contract administration, and project controls may use this method to calculate the following:

$$\text{Percent Complete} = \frac{\text{Actual Cost or WH to Date}}{\text{Forecast at Completion}} \text{ x } 100$$

## ADVANCED EARNED VALUE IMPLEMENTATION

A well executed EVMS is a power tool to achieve an effective project controls/management. Several papers have been published to further enhance the effectiveness of implementing earned value.

Jan Evensmo and Jan Karlsen in their paper, *Earned Value: The Hammer Without Nails?,* examined the six different developments of possible relationship of cumulative "planned," "earned" and "actual." Five different strategies were offered to manage each development pattern. Figure 4 is #5 of the six developments. [3]

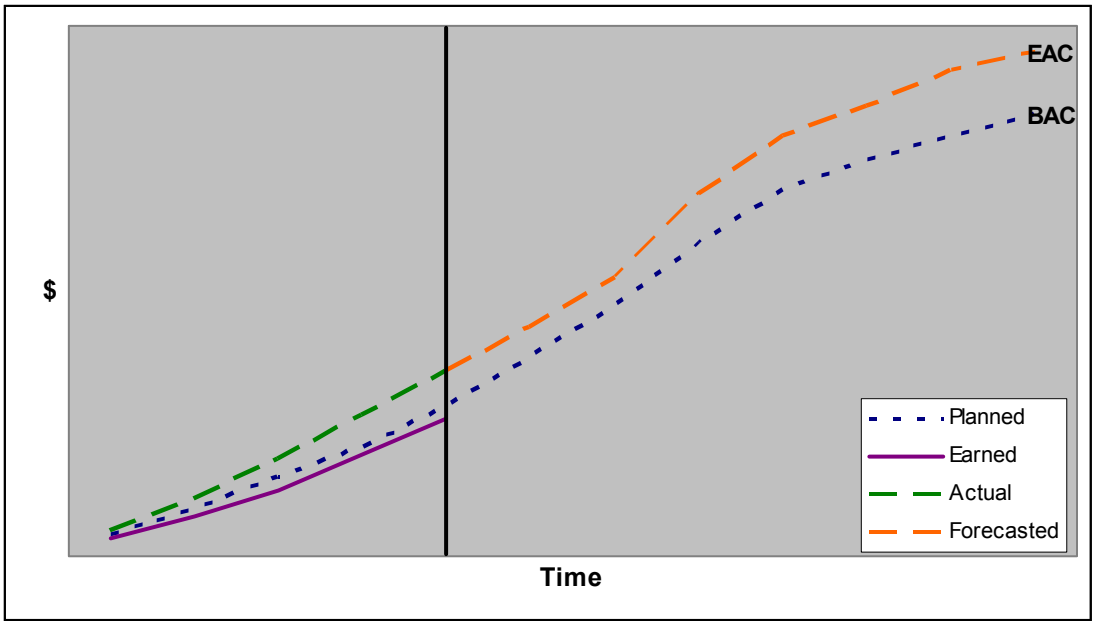


**Figure 4 – Example of Project Development**

Potential project risk mitigation strategies depend on the type of development. For #5 development, possible strategies include the following:

- Continue as before – resulting in delay and over budget.
- Change efficiency – work more efficiently to maintain both budget and schedule.
- Change scope (or quality) – reduce scope to maintain both budget and schedule.
- Maintain original schedule – use more resources (crashing technique) with cost overrun. And,
- Maintain original budget – use less resources, but increase delay.

A new concept of cost–time–risk diagram (CTR) was presented in the Perrapong Aramvareekul and Daniel J. Seider joint paper *Cost–Time–Risk Diagram: Project Planning and Management* [1]. CTR is a diagram that illustrates current project cost and time performance status associated with evaluated risks. It represents an advanced graphical analysis of earned value management similar to a project health-monitoring map. The diagram also provides risky and healthy cost / schedule boundaries at each period of time during the project life cycle.

A refreshing approach to assess the probabilistic EAC values was presented by H. Lance Stephenson in *Identifying Risks and Opportunities Using EAC* [10]. PERT technique is used to measure the unpredictability of the EAC values with ease. Based on the dispersion or range of EAC values, the expected value is calculated to assist risk management.

## BENEFITS AND EFFORT ASSOCIATED WITH EARNED VALUE

Beyond answering the simple question, "What did I receive for what I spent?" there are many more benefits to implementing earned value. Key benefits include the following: [6]

- Motivating/driving project team members to define scope of work, WBS, sequence of work packages, and the needed resources prior to executing a project.
- Ability to measure progress more objectively.
- Ease of communicating a time-phased schedule of values (planned), progress (earned), and effort spent (actual) to all stakeholders.
- Providing early warning of potential schedule and/or cost problems to prompt proactive action. And,
- Capability to forecast the project's final outcome (i.e., EAC) using performance trending analysis.

To capture these benefits, additional effort is required reflecting a natural benefit and cost relationship. Typical extra efforts include:

- Firm commitment from stakeholders to implement EVMS.
- More structure and discipline than non-earned value approach to complete prerequisites of EVMS.
- Need for more resources (people, $ and equipment) to develop and implement EVMS. And,
- Increasing report generation and data processing.

The quest to answer the fundamental question, "What did I receive for what I spent?" prompted the earned value concept. The concept has been continuously refined. The modern EVMS has become a simple and effective tool to detect early warning signs and contain project risks. Bad news never gets better with time. The earlier you sense the problem, the better chance you will have to mitigate the problem. [5]

It is essential to provide orientation/education of earned value basic concepts to all project participants. This will strengthen the commitment and support to implement an effective EVMS, and the project health status is more objectively and clearly communicated. The project team is able to take proactive actions as potential problems first occur. The benefits of earned value outweigh the extra effort to implement EVMS. Finally, the ability to forecast project final costs (EAC) with confidence during the project life cycle is further enhanced by earned value management.

**REFERENCES**


1. Aramvareekul, Peerapong and Daniel J. Seider. *Cost–Time–Risk Diagram: Project Planning and Management,* **Cost Engineering**, November 2006, pp. 12-18.
2. Chen, Mark T. *Applying Earned Value Procedure to Engineering Management,* 1991 **AACE International Transactions**, O.4.1-O.4.5.
3. Evensmo, Jan and Karlsen, Jan Terje. *Earned Value: The Hammer Without Nails?,* 2005 **AACE International Transactions**, pp. CSC.12.1-CSC.12.7.
4. Fleming, Quentin W. and Joel M. Koppelman, *The Essence and Evolution of Earned Value,* 1994 **AACE International Transactions**, CSC.13.1-CSC.13.7.
5. Fleming, Quentin W. and Joel M. Koppelman, *Using Earned Value Management,* **Cost Engineering**, September 2002, pp. 32-36.
6. Lambert, Lee R. *Understanding the Value of Earned Value or Where Have All Your Dollars Gone?,* 1989 **AACE International Transactions**, pp. H.2.1-H.2.4.
7. Longworth, Scott R. *Evolving Project Control Practices,* 2002 **AACE International Transactions**, pp. CSC.04.1-CSC.04.9.
8. Prentice, Jean-Paul. *Earned Value in the Construction and Facilities Maintenance Environments,* 2003 **AACE International Transactions**, pp. CSC.17.1-CSC.17.4.
9. *Skills and Knowledge of Cost Engineering, 5th Edition,* **AACE International**, Appendix A.
10. Stephenson, H. Lance. *Identifying Risks and Opportunities Using EAC,* 2004 **AACE International Transactions**, pp. CSC.06.1-CSC.06.9.
11. Tague, Thomas and Morrison, Franklin. *Einstein's Percent Complete,* **Cost Engineering**, September 2007, pp. 12-15.
12. Wageman, Steven W. *Lifting the Fog on Earned Value – Applied EV Methods That Can Be Used On (Almost) Any Project,* **AACE Seattle Section Presentation**, November 2006.
13. Warhoe, Stephen P. *The Basics of Earned Value Management,* 2004 **AACE International Transactions**, pp. CSC.07.1-CSC.07.10.
14. Yonezawa, Tetsuya. *Practical EVMS for an EPC Project,* 2005 **AACE International Transactions**, pp. CSC.18.1-CSC.18.7.



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