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An Earned Value Tutorial

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Introduction

The Earned Value Method suffers from its complicated history. Introduced in the 1960s by the Department of Defense as a method for managing projects, it was quickly driven into disfavor by its "alphabet soup" of abbreviations and its well intentioned, but misapplied, accounting requirements.

Nowadays, things are looking up for the Earned Value Method. In 2000, The Project Management Institute (PMI®) published a revised *Guide to the Project Management Body of Knowledge* (*PMBOK® Guide*) that banished the arcane abbreviations. The Institute also included 15-20 Earned Value questions on the Project Management Professional (PMP®) Certification Examination. By simplifying the ideas of Earned Value and requiring its mastery for certification, PMI hopes that project managers will take advantage of this method more often.

To help you capitalize on Earned Value, this tutorial will show you how to apply it, even to your simplest projects.

Background: What Is Earned Value?

Earned Value (EV) is a method for managing projects based on the regular comparison of actual project costs to planned costs *and* to completed work. The name "Earned Value" comes from the idea that each project deliverable has a planned cost, its "value," and when the deliverable is completed, its "value" is "earned" by the project.

While comparing actual cost to planned cost is a common practice on projects, the added step of comparing actual cost to the planned cost of completed work is not. It is this step however that makes the EV method powerful and objective. The objectivity comes from the assessment of completion. Percent completion assessments often require subjective judgment. "Done," "Not Done" assessments don't. A deliverable is either complete or not, with little gray area in between.

How Does the Earned Value Method Work?

Successful EVM management requires several key practices:

- Identify each project deliverable
- Develop a schedule for the completion of each deliverable
- Assign a value to each deliverable

In other words, to manage using EV, the product, the schedule, and the cost of our project must be determined *before* we start. The good news – if you already practice good project planning techniques, the information you need will be easy to find.
To demonstrate, we'll try it on a hypothetical project to replace the deck of a house.

Product of the Project

The product of this project is a new second-story deck. This new deck will replace an existing deck, stand about 10 feet off the ground, and measure 12 feet by 12 feet square. On one side, a set of stairs will lead to the ground. The structure will be attached to the house and supported with four posts resting on concrete footings. Since the house is located in New England, the footings must extend below the frost line (about 4 feet). The homeowner and friends (when available) will construct the deck with standard materials. All supplies will be ordered from and delivered by the local home improvement center.

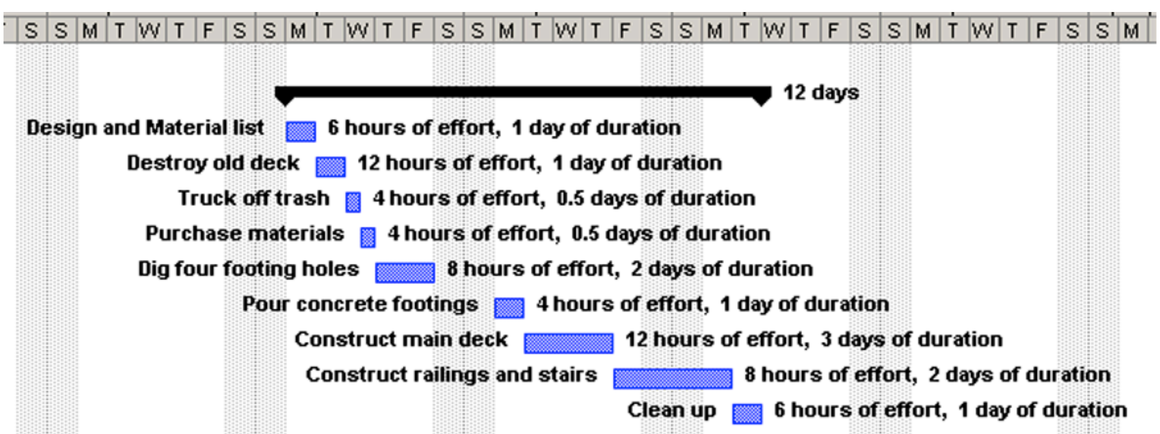
Table 1 details the work of the project as a list of activities in the first column and the cost estimates for each activity in the second column. For cost, we have assumed that labor hours are the simplest units to use for valuing each project activity. Using hours to value work translates well in the business world because salary information is not generally available.

The third column of Table 1 contains the estimated planned duration for each activity. These estimates are necessary (but not sufficient) for generating a schedule of the work and filling in the "Scheduled Finish" column.

Table 1. *Planned Values for Deck Replacement Project*

	Activity	Planned Cost (Effort-Hours)	Planned Duration (Days)	Scheduled Finish (Day)	Actual Cost (Effort-Hours)	Status (Done/ Started)	Earned Value (Effort-Hours)
1	Draw plans and materials list	6	1				
2	Destroy old deck	12	1				
3	Truck off trash	4	0.5				
4	Purchase materials	4	0.5				
5	Dig four footing holes	8	2				
6	Pour concrete footings	4	1				
7	Construct main deck	12	3				
8	Construct railings and stairs	8	2				
9	Clean-up	6	1				
	Total	**64 Hours**					

Figure 1. *Schedule of Deck Replacement Project Activities*



Project Schedule

Our final step is to sequence each activity relative to all other activities in the project. This schedule, along with the activity durations, allows us to create the Gantt chart in Figure 1 (above). Because of the added features of Microsoft Project, we are also able to show the effort and duration for each task (to the right of the task bar) and a summary bar that spans the duration of the project.

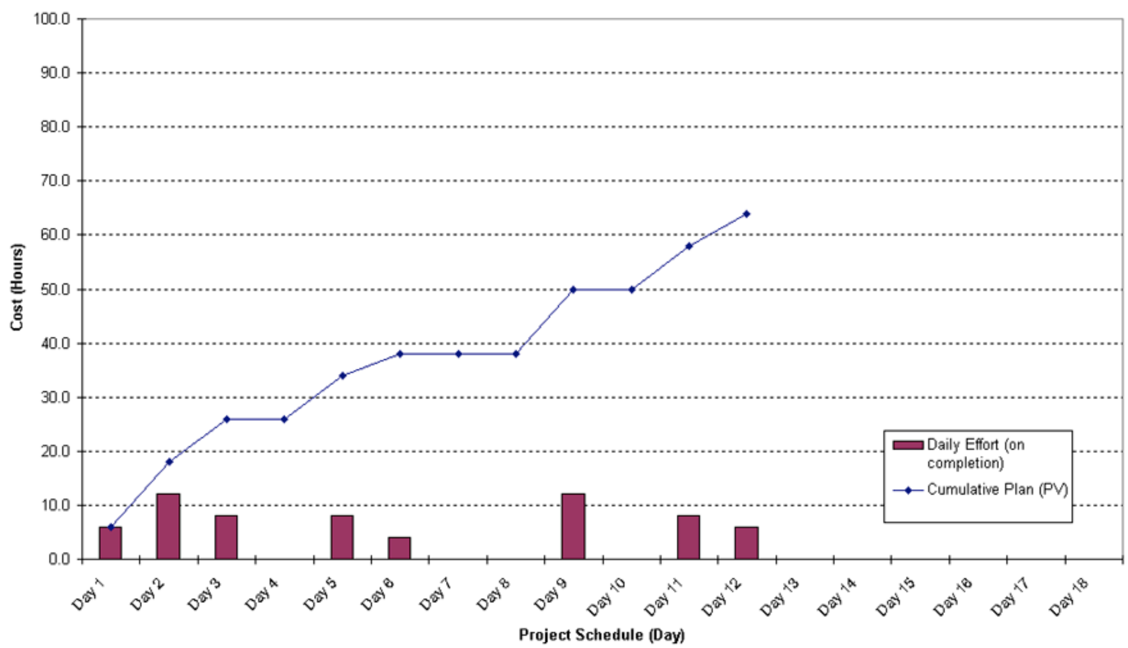
Setting the Baseline

Having scoped the project, estimated its costs (effort), and scheduled each activity, we are ready to produce a plan baseline. To accomplish this, the planned effort hours are spread out and accumulated over the duration of the project.

For our deck project, the total duration is 12 days with 64 hours of total effort. Figure 2 shows the effort hours by day (as bars) and the cumulative effort hours (as a line). The height of the line on Day 12 is 64 hours, which corresponds to our total cost. In EV terminology, this cumulative plot is called the *Performance Measurement Baseline* (Baseline for short) or *Planned Value* (PV).

To generate the baseline, accumulate the planned effort for each task on the day the task should have been completed. This completion-day accumulation explains days with no identified effort as well as the somewhat jagged baseline. When the tasks are short, this approach is works well. When project tasks last several weeks, distribute the effort evenly over the weeks to smooth out the baseline and to better illustrate when the effort was expended.

Figure 2. *Daily and Cumulative Effort vs. Project Schedule*



Measuring Performance

Having completed the initial planning and constructed a baseline, we can now use the plan to guide execution of the project and track our progress. Table 2 shows the actual effort hours spent and whether the task has been fully completed. Actual effort has been recorded in the Actual Cost column and the status of each activity in the Status column. Notice that the entries in the status column are either "Started" or "Done." Only when an activity is marked "Done" do we "earn" the planned value for completed work and enter

Table 2. Planned and Actual Results

	Activity	Planned Cost (Effort-Hours)	Planned Duration (Days)	Scheduled Finish (day)	Actual Cost (Effort-Hours)	Status (Done/ Started)	Earned Value (Effort-Hours)
1	Draw plans and materials list	6	1	Day 1	6	Done	6
2	Destroy old deck	12	1	Day 2	12	Done	12
3	Truck off trash	4	0.5	Day 3	4	Done	4
4	Purchase materials	4	0.5	Day 3	4	Done	4
5	Dig four footing holes	8	2	Day 5	10	Started	0
≫	**Total-To-Date**	**34**			**36**		**26**
6	Pour concrete footings	4	1	Day 6			
7	Construct main deck	12	3	Day 9			
8	Construct railings and stairs	8	2	Day 11			
9	Clean-up	6	1	Day 12			

the Planned Value in the Earned Value column. Also notice that until an activity is complete, we do not earn *any* of its value. In other words, no partial credit is awarded.[1]

Day 5 of the Project

Let's summarize our data as of Day 5. According to Table 2, we had planned to expend 34 hours of effort on the project (the sum of the planned cost for the first five activities). Those 34 hours were to complete the first five activities.

However, based on actual results, we have expended 36 hours and completed the first four activities. Activity 5, "Dig footings", has started, but is not yet finished and it is running over plan (the planned effort was 8 hours, recorded actuals show 10 hours so far). And since the digging is not done, we can't take any credit for Earned Value on the activity.

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[1] If a laborer has completed digging 50 feet of a 100-foot trench, the activity is clearly 50% complete. But good luck to the process engineer who tries to report 50% complete on a new process design.

While many support the idea of "percent complete" (including Microsoft Project), white-collar projects are a poor place for this practice. White-collar work is not typically made up of measurable interim deliverables. Lacking these markers, an estimate of "percent complete" is subject to negotiation between the team member and the project manager. As such, it is unreliable.

Eliminating "percent complete" accounting is necessary to objectively assess project status. When planning, break each deliverable into small work packages that can be completed in one to two reporting periods. At status meetings, have team members report actual hours spent on the task, and report *only* "Done" or "Not Done." Record the hours and enter "0%" or "100%" complete.

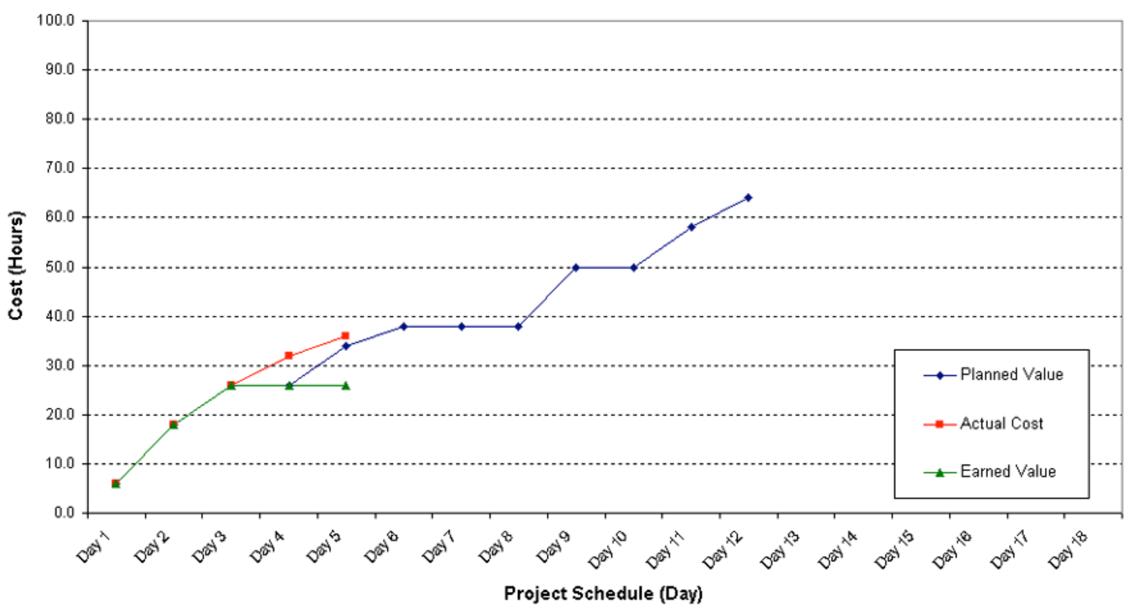
The calculation of the project's Earned Value (planned value for completed work) will be slightly lower than the actual hours expended (because no value is earned for incomplete tasks) but the difference will be small relative to the total project (because the tasks are small) and have only a minor impact on the Earned Value calculations. (Of course, you'll also benefit from a more detailed project plan and by having each team member reporting activity status regularly and frequently.)

What Is the Status of Our Project?

Now let's look at what the numbers really mean. At the end of Day 5, we planned to accomplish 34 hours of work. We've expended 36 hours, yet we've only earned 26 hours.

One way to evaluate our project's status is to graph our results. Figure 3 shows our Planned Value (blue diamonds line), Actual Cost (red squares line), and Earned Value (green triangles line) plotted against project duration.

Figure 3. *Planned Value, Actual Cost & Earned Value vs. Project Duration Through Day 5*



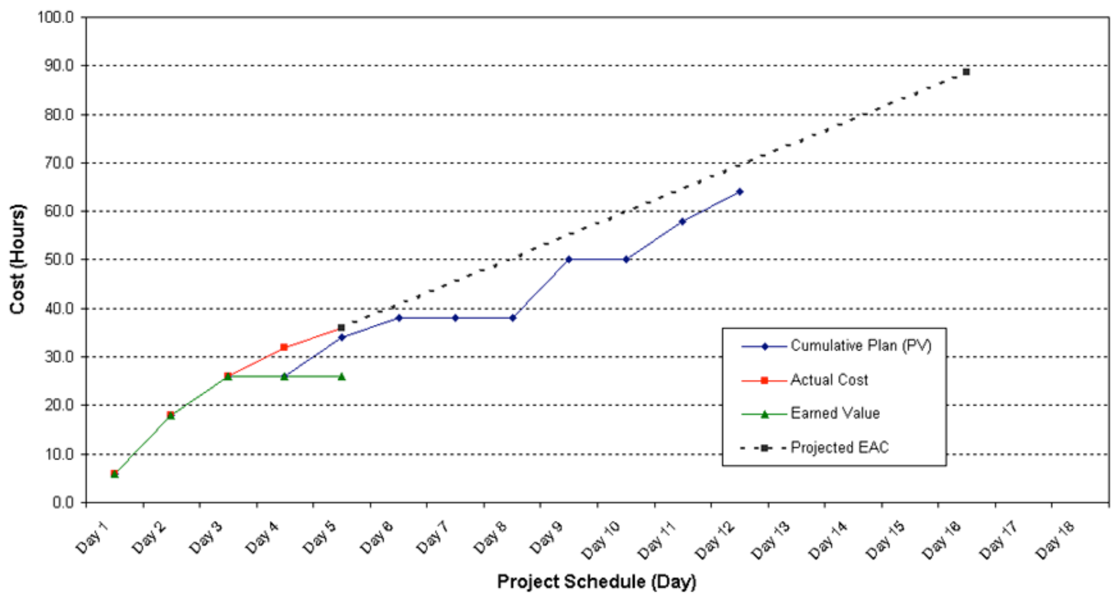
By comparing the Actual Cost line to the Planned Value line, we can see that, through Day 3 of the project, actual costs were according to plan. But on Day 4, the red jumps above the blue, showing that we've gone over plan. Also, because no work was marked "Done" on Days 4 or 5, the Earned Value (green line) levels off. The gap between Actual Cost, Planned Value, and Earned Value clearly indicates project problems.

To confirm what the graph is telling us, let's look at the numbers. We'll use two Earned Value ratios: the Cost Performance Index (CPI) and the Schedule Performance Index (SPI). The CPI is the ratio of Earned Value divided by Actual Cost, and the SPI is the ratio of Earned Value divided by Planned Value. Both ratios are calculated using "To Date" cumulative values.

Doing the math, we find that CPI = 26/36 = 0.72 and SPI = 26/34 = 0.76. Think of the CPI and the SPI as project productivity measures. Based on our CPI, we are realizing 7.2 hours of result for every 10 hours of actual effort expended on our project. Based on our SPI, we are realizing 7.6 hours of result for every 10 hours of planned effort on our project. (Imagine putting a dollar in a change machine and getting only 72 or 76 cents back. Would you be pleased?)

If these ratios are accurate, we can use them to forecast completion of the project. To forecast the estimated cost at completion (EAC), divide the original cost by the CPI. For our project, EAC = 64 / 0.72 = 88.6 hours. The Forecasted Duration is the original duration divided by the SPI. Again, for our project, Forecasted Duration = 12 / 0.76 = 15.7 days (see Figure 4[2]).

Figure 4. *Forecast of Project EAC and Duration using CPI and SPI*



So after five days of work on the project, it looks like we've added more than three days to the schedule and 22 hours of work to the budget. Is the project really *that* far off track? (CPI and SPI are conservative forecasting tools – each assumes that past performance is an indicator of future results.)

How Bad Is It?

If we examine our deck project closely, we'll see that Activity 5 is seriously over budget and not yet complete. The hole-digging activity seems to have run into trouble – after ten hours of work (two more than planned), the work is not done. Activity 5 has also lowered the SPI because the project cannot take credit for its completion.

Things do look pretty grim. With Activity 5 over budget by 25% and climbing, how can we get this project back on course? First, we need to figure out what happened. Then we can take corrective action.

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[2] There are many ways to forecast EAC; this equation is the least questionable. See reference 1 for a thorough discussion of EAC.

What Happened?

After a review and discussion of the project's performance, our key stakeholders discovered that the original estimates for digging were based on favorable soil conditions. For three of the four holes, this was a valid assumption. However, the diggers uncovered a large boulder (more than 500 lbs) on the fourth hole.

Aside from the fourth hole, the other project tasks completed as planned and raised no concerns about the estimates for work not yet started.

So our project is not quite as badly off as the numbers suggest. Three of the four holes are complete, and the fourth hole would be done if not for the boulder. If we informally apply a "% complete" evaluation to our project, we earn 75% of the hole digging activity. This increases our Earned Value to 32 hours, and our CPI and SPI to 0.89 and 0.94 respectively. If we recompute the EAC and schedule, our EAC forecast improves from 88 to 72 hours and we shorten our schedule estimate from 15.7 days to 12.7 days. This information will help us decide on what corrective action to take.

Corrective Action

The right corrective action depends heavily on the kinds of problems encountered and how the project stakeholders weigh the various solutions. For example, a key stakeholder (a spouse in this case) may insist that product cannot be compromised ("It won't look right"), or may focus on schedule because of an upcoming social event.

Table 3 lists possible stakeholder responses for the deck project. The table assumes that the stakeholder holds firm on one of the key project constraints while being flexible on the other two.

Table 3. *Possible Corrective Action for the Deck Project (continued on next page)*

Stakeholder Priority	General Approach	Possible Specific Approaches
Maintain project schedule	Sacrifice product	• Reduce the scope of some other part of the project. For example, use simpler hand railings • Stop digging and hope the building inspector doesn't notice the depth of the hole with the rock
	Sacrifice cost	• Work overtime to finish the task before the start of Day 6 • Have a friend help (more pizza and beer) • Rent a back-hoe
Maintain product features and performance	Sacrifice schedule	• Get permission from the stakeholders • Run late, then beg forgiveness from the stakeholders
	Sacrifice cost	• Work overtime to finish the task before the start of Day 6 • Have a friend help (more pizza and beer) • Rent a back-hoe

Maintain project cost	Sacrifice product	• Reduce the scope of some other part of the project. For example, use simpler hand rails • Stop digging and hope the building inspector doesn't notice the depth of the hole with the big rock
	Sacrifice schedule	• Since we have already gone over budget, changing schedule will have little impact on project cost

After some discussion, the stakeholders decided that the key constraint is the product's features and performance. They chose to remove the bolder and place the footing where originally planned, satisfying all building codes. However, since this choice adds work to the project, the plan must be adjusted.

Re-Baseline

Removing the rock involved manually excavating around it, dragging it out of the hole, and restoring the earth displaced by the rock. In total, an additional eight hours of effort and one day of schedule need to be added.

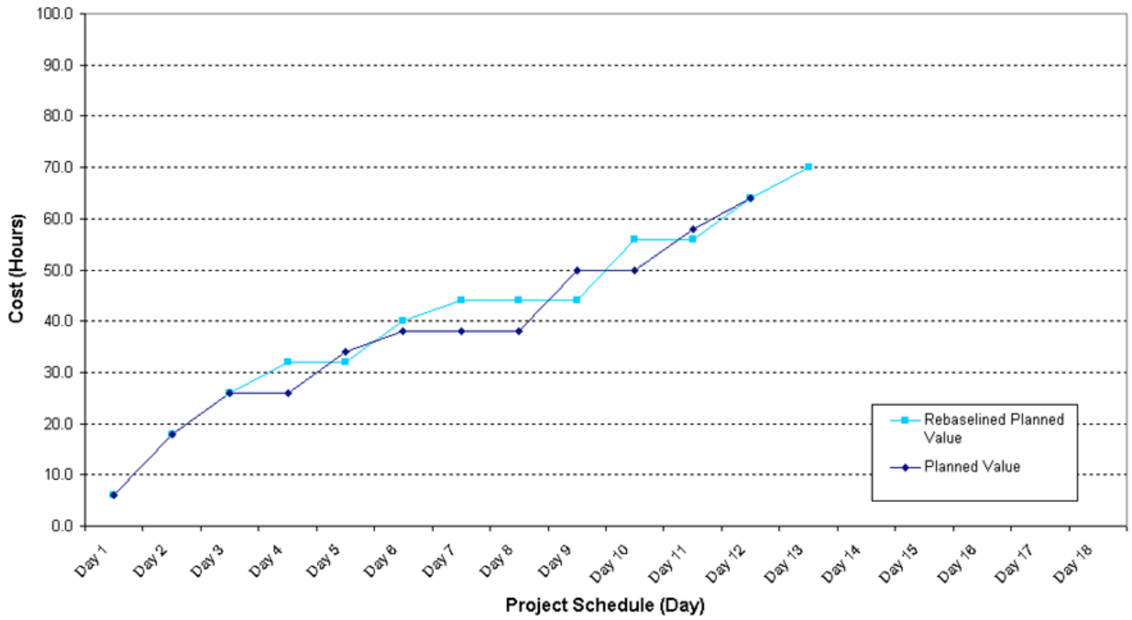
Table 4 shows the updated plan reflecting the added task "Remove boulder." No other project activities have been changed. Also, the activity "Dig footings" was marked "Done" and the value of that work counted as "Earned".

Table 4. *Re-Baselined and Planned with Actual Results (replaced values in parentheses*)

	Activity	Planned Cost (Effort-Hours)	Planned Duration (Days)	Scheduled Finish (day)	Actual Cost (Effort-Hours)	Status (Done/ Started)	Earned Value (Effort-Hours)
1	Draw plans and materials list	6	1	Day 1	6	Done	6
2	Destroy old deck	12	1	Day 2	12	Done	12
3	Truck off trash	4	0.5	Day 3	4	Done	4
4	Purchase materials	4	0.5	Day 3	4	Done	4
5	Dig four footing holes	8	2	Day 5	8	Done	8
6	**Remove boulder**	**8**	**1**	**Day 6**	**2**	**Started**	
7	Pour concrete footings	4	1	Day 7 *(6)*			
8	Construct main deck	12	3	Day 10 *(9)*			
9	Construct railings and stairs	8	2	Day 12 *(11)*			
10	Clean-up	6	1	Day 13 *(12)*			
	Total	**72 *(64)* Hours**			**36**		**34**

Figure 5 compares the original baseline plot to the new baseline. The total project effort has been increased to 72 hours (from 64) and the duration has increased from 12 to 13 days.

Figure 5. *Original Baseline and Re-Baselined Planned Value*



The effect of the re-baseline can be evaluated quickly with CPI, SPI, and their related projections. At the end of Day 5, we have a new CPI = 32/36 = 0.89 and the new SPI = 32/32 = 1.0. The new EAC = 72/0.89 = 80 hours. The projected duration is the same as the re-baselined plan, or 13/1.0 = 13.

The project is still forecasted to exceed the new budget (because CPI is less than 1.0), due to two hours of rock removal on Day 5 (two hours against the eight hours added during the re-baseline). We expect that after Day 6, CPI productivity will climb back to 1.0.

Re-baselining is only legitimate when it is performed in response to a stakeholder-approved scope change.

Summary and Conclusions

Effective project planning provides us with the data needed to implement the Earned Value Method. Proper, data collection allows us to calculate the ratios of Cost Performance Index and Schedule Performance Index. These ratios, combined with our original plan, tell us where we are and where we are headed. While the process can sometimes produce bleak forecasts, the Earned Value Method generates a conservative and unambiguous assessment of our project's status that allows us to steer a better course towards our goal.

In short, we can best decide where we want to go when we know where we are.

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About the Author

Mark Durrenberger was a co-founder of Oak Associates, Inc., a predecessor company to New Leaf. He has been teaching project managers since 1995. Mark has fifteen years of experience managing IT, high-technology new-product development, and organizational change projects in large corporations. He has published articles on project management tools and techniques and given talks on a variety of project management topics. Mark is a graduate of the University of Lowell (Massachusetts) with a B.S. in Nuclear Engineering and a M.S. in Energy Engineering. He was certified by the Project Management Institute (PMI®) as a Project Management Professional (PMP) in 1994.

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