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Earned Value: Ideas and Exercises
(for PMBOK 5th Edition)

Exercises to calculate earned value and other project metrics

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Introduction

Earned value calculations can give a project manager a picture of the project's progress to date. With this information the manager can project the total project cost and schedule and then make appropriate adjustments to the project. The exercises in this article will show you how to predict where your project is going so you can make adjustments before it's too late.

The project shown in Figure 1 below has an original cost, or Budget at Completion (BAC), of 1000 staff-days and an original schedule of 10 months. The calculations begin with the "s-curve" chart of information that depicts the project's planned value from start to end, and two actual lines from the project start to the current date. One of the two "actual" lines depicts the actual cumulative cost to date, the other the actual cumulative earned value to date. The last bits of information in the graph are the present date and the planned value to date.

Figure 1. A typical earned value chart.

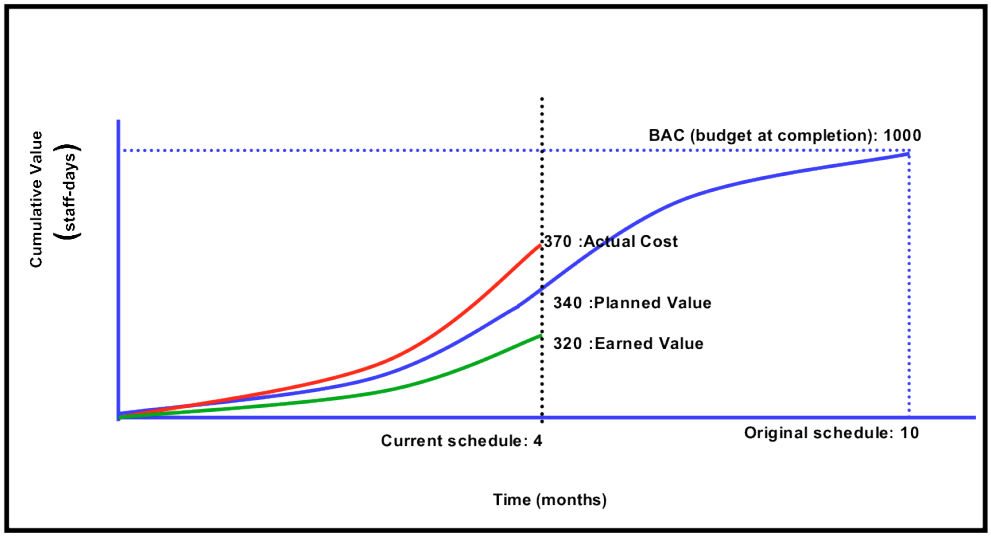

Figure 2. A typical project task list.

Task List

Task name	Plan	Actual	Earned Value	Date completed Planned	Actual
. . .					
MONTH 3	240	268	238		31-Mar
Pink	16	14	16	2-Apr	5-Apr
Violet	12	16	12	5-Apr	10-Apr
Red	18	22	18	5-Apr	8-Apr
Vermillion	8	10	8	15-Apr	20-Apr
Blue	18	24	18	20-Apr	18-Apr
Brown	8			22-Apr	
Green	10	16	10	22-Apr	28-Apr
Yellow	10			25-Apr	
MONTH 4	340	370	320		30-Apr
Brown*	*			22-Apr	
Yellow*	*			25-Apr	
Beige	2			2-May	
Apricot	2			5-May	
Pink	3			5-May	
. . .					

Terms

Earned value is an expression of cumulative achievement, or what has been accomplished "to date." In Figure 1 the vertical axis is labeled "Cumulative Value" and *three measures* of accumulated (or "to date") activity are graphed across the horizontal project duration.

> *Planned Value.* The first of the three measures is the planned value, the sum of the budgets (including overhead) for all activities scheduled to be worked on within a given period of time (in our example, the periods are the whole project and the project-to-date).
>
> *Actual Cost*. The second measure is the total cost incurred in accomplishing the project objectives during a given time period (in our example, the project-to-date).
>
> *Earned Value*. The third measure is the sum of the budgets (including overhead) for all the activities that have been completed to date.

The units of value are most commonly staff-hours for white-collar projects, but they could just as well be dollars, staff-days ("stays"), staff-months, or milestones. To simplify the numbers, the units of value in this example will be *staff-days*.

In the exercises that follow, the units will vary.

Background

In order to use earned value analysis to help assess a project's performance to date, the project must have begun with a plan that assigns a value to each task. This value is the "planned" value that can later be "earned" when the activity is completed. These values appear in the plan's task table, part of which is shown in Figure 2. (The words *task* and *activity* will be used

interchangeably in this article.) The task table shows that Month 4's activities have been totaled to arrive at the 370, 340 and 320 cumulative staff-days shown in the diagram in Figure 1.

The monthly cumulative totals count only those tasks that have been completed. Two tasks, “Yellow” and "Brown," have not been worked on and will be rolled forward into the next month's accounting.

CPI and SPI Are Stable
Data from hundreds of projects have shown that a project’s earned value behavior, as represented by the CPI and the SPI, *stabilizes* within the first 15% of the project’s schedule and remains relatively constant over the remaining 85%. This stability allows these ratios to be used with confidence.

Simplifying Assumption
Sometimes a task is only partially complete at the end of a measuring period. In order to make our calculations simple, we will **assume in all our examples that there are no partially completed tasks**. At the moment of measurement, all tasks either have been totally completed or have not started.

A Typical Problem
In the example in Figures 1 and 2, the total plan for the project involved 1000 staff-days of value (the Budgeted at Completion or BAC) accumulated over 10 months with a staff of 5 full-time people. At the 4-month mark, with no open tasks, the total accumulated earned value is 320 staff-days. The plan at this point is for 340 staff-days to have been earned. Alas, the actual amount spent (because extra staff time has already been spent on this project) is 370 staff-days.

A summary of the facts:

1. Original project cost: 1000 staff-days
2. Original project schedule: 10 months
3. Planned value: 340 staff-days at 4 months
4. Actual cost: 370 staff-days
5. Earned value: 320 staff-days
6. Current monthly staff: 5 people

The earned value questions that are often asked are:

1. What is the current cost shortfall in as measured by the Cost Variance (CV?
2. What is the current work productivity as measured by the Cost Performance Index (CPI?
3. What is the current schedule shortfall in as measured by the Schedule Variance (SV?
4. What is the current schedule efficiency as measured by the Schedule Performance Index (SPI?
5. What is the projected total cost Estimate at Completion (EAC)?
   a. If we assume cost variance was *atypical* (and the rest of the project will go as originally planned)?
   b. If we assume cost variance was *typical* [recommended by New Leaf] (and the rest of the project will have a proportional variance)?
   c. If we assume we can re-plan the remaining project and make a whole new estimate?

6. What is the projected schedule Estimate at Completion (EAC_t)?
   a. If we assume schedule variance was *atypical* (and the rest of the project will be as originally planned)?
   b. If we assume schedule variance was *typical* [recommended by New Leaf] (and the rest of the project will have a proportional variance)?
   c. If we assume we can re-plan the remaining project and make a whole new estimate?
7. What are the remaining cost-to-complete and schedule-to-complete figures for each of a, b, and c?
8. What is the intensity of work required to finish the work with the available funds? (These funds can be defined as either the original Budget at Completion (BAC) or the current Cost Estimate at Completion (EAC).)
9. And, if making the original schedule is important, what are the Remaining Work Index (RWI) and the Staffing-to-Schedule Index (StSI) – [both invented by Nevison], and how do these indexes suggest that we recover the schedule and preserve the shape of the project's staffing pattern?

CV and CPI?
The Cost Variance is the earned value minus the actual cost. The Cost Performance Index is the earned value divided by the actual cost of the project-to-date. If everything is going according to plan the cost variance is 0 and the CPI is 1.0. However, the cost variance is usually negative and the CPI is usually less than 1.

In this example we have completed 320 staff-days of earned value with 370 staff-days of effort.

Cost Variance = 320 – 370 = -50
Cost Performance Index = 320 / 370 = .86

Note: Because the CV is usually negative, we will call a negative CV a *cost shortfall* and define it to be the absolute value of the negative cost variance [New Leaf definition].

Section 1.01 Cost Shortfall = |-50| = 50

SV and SPI?
The Schedule Variance (SV) is the earned value minus the planned value. The Schedule Performance Index (SPI) is the earned value divided by the planned value (of the project-to-date). If the project is going according to plan the Schedule Variance is 0 and the SPI is 1.0. However, the Schedule Variance is usually negative and the SPI is usually less than 1.

In this example we have completed 320 staff-days of earned value in the time we had planned to complete 340 staff-days of planned value.

Schedule Variance = 320 – 340 = -20
Schedule Performance Index = 320 / 340 = .94

Note: Because the SV is usually negative, we will call a negative SV a *schedule shortfall* and define it to be the absolute value of the negative schedule variance. [New Leaf definition]

Schedule Shortfall = |-20| = 20

Projected Total Cost?
To decide on a cost Estimate at Completion (EAC) we must decide how our project will behave between now and the end.

a. If we assume the cost variance was *atypical* and *the rest of the work will be performed at the original budgeted rate*, then the cost EAC will be the original Budget at Completion plus the current *cost shortfall*. In our example:

   Cost EAC (if atypical variance) = 1000 + |320 – 370| = 1050 staff days

b. If we assume the cost variance was *typical* [recommended by New Leaf] and *the rest of the work will be performed at the present CPI*, then the cost EAC will be the original Budget at Completion, or BAC, divided by the Cost Performance Index, or CPI. In our example:

   Cost Estimate at Completion (EAC) = 1000 / (320 / 370) = 1000 / 0.86 = 1156 staff-days

c. If we assume we can re-plan the remaining project and make a whole new estimate, then the EAC is the some number larger than the current actual cost.

Projected Schedule?
To find a Schedule Estimate at Completion (EAC_t), we must decide on how our project will behave between now and when it ends.

a. If we assume schedule variance was *atypical* and *the rest of the work will be performed at the original budgeted rate*, then the schedule EAC_t will be the original schedule times (the original budget plus the present schedule shortfall)/(the original budget). This is a New Leaf formula that is not included in the *PMBOK 4th*.
   In our example:

   Schedule EAC_t (if atypical variance) = 10 x (1000 +20)/1000 = 10 x 1.02 = 10.2 months [New Leaf formula]

b. If we assume the schedule variance was *typical* [recommended by New Leaf] and *the rest of the work will be performed at the present SPI*, then the schedule EAC_t will be the original schedule divided by the schedule performance index, or SPI. In our example:

   Schedule Estimate at Completion (EAC_t) = 10 / (320 / 340) = 10 / 0.94 = 10.6 months

c. If we assume we can make a whole new estimate, then the new schedule is some date later than the current actual date.

Cost ETC?
To make a cost Estimate to Completion (ETC), we must decide how our project will behave between now and the end.

a. If we assume the cost variance was *atypical* and *the rest of the work will be performed at the original budgeted rate*, then the cost ETC will be the difference between our atypical-variance cost EAC and the current actual cost. In this example:

Cost ETC (if atypical variance) = 1050 - 370 = 680 staff days

b. If we assume the cost variance was *typical* [recommended by New Leaf] and *the rest of the work will be performed at the present CPI*, then the cost ETC will be the typical-variance cost EAC less the current actual cost. In our example:

Cost Estimate to Completion (ETC) = 1156 – 370 = 786 staff-days

c. If we assume we can re-plan the remaining project and make a whole new estimate, then the ETC is a new value that is the result of our re-plan.

Remaining Schedule? (Schedule ETC_t)

The *PMBOK*$^{(C)}$ *4th* uses the term "remaining schedule." It does not use the term or the abbreviation "schedule ETC_t." The term "schedule ETC_t" is a New Leaf term that parallels the cost ETC. To find the remaining schedule (a "Schedule Estimate to Complete"), we must decide on how our project will behave between now and when it ends.

a. If we assume schedule variance was *atypical* and *the rest of the work will be performed at the original budgeted rate*, then the remaining schedule will be the atypical-variance schedule EAC_t less the present time. In this example:

Remaining schedule (with an atypical variance) = 10.2 – 4 = 6.2 months

b. If we assume the schedule variance was *typical* [recommended by New Leaf] and *the rest of the work will be performed at the present SPI*, then the remaining schedule will be the schedule EAC_t less the present time. In our example:

Remaining schedule (with typical variance) = 10.6 – 4 = 6.6 months

c. If we assume we can make a whole new estimate, then the remaining schedule is the difference between the new end date and the current actual date.

To-Complete Performance Index (TCPI)?

To make a To-Complete Performance Index (TCPI), we must decide whether we are indexing on our original budget (BAC) or on our current Cost Estimate at Completion (EAC). In either case, the TCPI will measure the "work remaining over the funds remaining" and tell us how efficiently we will need to work to meet our goals with the target funds.

The TCPI is the only index where *bad news is greater than 1.0*, while good news is less than 1.0.

If we assume that we want to complete within the BAC, then the TCPI is the work remaining, (BAC – EV), divided by the funds remaining (BAC – Actual Costs). In this example:

To-Complete Performance Index (TCPI) = (1000 – 320) / (1000 – 370) = 680/630 = 1.08

We must work with a greater cost efficiency than originally planned if we are to finish within our original BAC.

If the BAC is no longer a reasonable goal, we assume we will want to complete within the current EAC and the TCPI becomes the work remaining, (BAC – EV), divided by the funds remaining (EAC – Actual Costs). In this example:

To-Complete Performance Index (TCPI) = (1000 – 320) / (1156 – 370) = 680/786 = .87

We can work with a lower cost efficiency than originally planned and still finish within our current EAC.

How Many Extra People?
To calculate the number of extra people needed to finish on time, follow these four steps: [Nevison invented both the RWI and the StSI]

With a planned monthly staff = 5 people:

1. Remaining work index (RWI) = remaining planned work / remaining actual work
= (1000 – 340) / (1000 – 320)
= 660 / 680
= .97

*2. Staffing-to-schedule Index (StSI) = Remaining Work Index * CPI*
*= .97 * .86 = .84*

3. Workers needed per month = Planned staff / StSI
= 5 / .84 = 6.0 persons

4. Extra workers needed = persons needed – persons on board.
= 6 - 5 = 1.0 persons

Reservations
The 1.0 extra persons (extra full-time equivalents) in the above example is a *minimum* number. It makes several optimistic assumptions:

- The new people can be found right away
- The new people will be as productive as the old hands right away
- The larger team will communicate with the same efficiency
- The work can be accelerated by bringing on extra people

None of these assumptions is strictly true. So the prudent manager will want to bring on a little more than the number calculated in order to take effective corrective action. A simple rule of thumb is round up any fractional head count. In the above example where we need 1.0 persons and we have no fractional count, so we make sure we search for one very experienced person.

Exercises
Following are four exercises and their answers. *Please try each exercise on your own before checking on the answers.*

Exercise 1

A summary of the facts:

1. Original project cost: 1200 staff-days
2. Original project schedule: 12 months
3. Planned value: 500 staff-days at 5 months
4. Actual cost: 550
5. Earned value: 450
6. Current staffing: 5 full time people

Questions: (Staff-days and months)

1. What is the current Cost Variance (CV)?
2. What is the current Cost Performance Index (CPI)?
3. What is the current Schedule Variance (SV)?
4. What is the current Schedule Performance Index (SPI)?
5. What is the projected total cost estimate at completion (EAC)?
   a. If we assume cost variance was *atypical* (and *the rest of the work will be performed at the original budgeted rate*)?
   b. If we assume cost variance was *typical* [recommended by New Leaf] (and *the rest of the work will be performed at the present CPI*)?
6. What is the schedule "estimate at completion" or (EAC_t):
   a. If we assume schedule variance was *atypical* (and *the rest of the work will be performed at the original budgeted rate*)?
   b. If we assume schedule variance was *typical* [recommended by New Leaf] (*the rest of the work will be performed at the present SPI*)?
7. What are the remaining cost-to-complete and schedule-to-complete figures for *a* and *b*?
8. What is the To-Complete Performance Index (TCPI) for the BAC? The TCPI for the EAC with a *typical* cost variance?
9. If making the original schedule is important, what are the Remaining Work Index (RWI) and the Staffing-to-schedule Index (StSI), and what extra staffing is required to recover the original schedule?

Exercise 2

A summary of the facts:

1. Original project cost: 320 staff-days
2. Original project schedule: 4 months
3. Planned value: 80 staff-days at 1 month
4. Actual cost: 82
5. Earned value: 75
6. Current staffing: 4 people

Questions: (Staff-days and months)

1. CV: __ staff-days
2. CPI: __
3. SV: __ staff-days
4. SPI: __
5. Cost EAC a: __ staff-days b: __ staff-days
6. Schedule EAC_t: a: __ months b: __ months

7. CTC: a: __ staff-days b: __ staff-days
   Schedule-to-complete: a: __ months b: __ months
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

Exercise 3

A summary of the facts:

1. Original project cost: 1808 staff-hours
2. Original project schedule: 64.5 days
3. Planned value: 824 staff-hours at 32 days
4. Actual cost: 919
5. Earned value: 736
6. Current staff: 3.5

Questions: (Staff-hours and days)

1. CV: __ staff-hours
2. CPI: __
3. SV: __ staff-hours
4. SPI: __
5. Cost EAC: a: __ staff-hours b: __ staff-hours
6. Schedule EAC_t: a: __ days b: __ days
7. CTC: a: __ staff-hours b: __ staff-hours
   Schedule-to-complete: a: __ days b: __ days
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

Exercise 4

A summary of the facts:

1. Original project cost: 7368 staff-hours
2. Original project schedule: 48 weeks
3. Planned value: 4392 staff-hours at 29.4 weeks
4. Actual cost: 4144
5. Earned value: 3632
6. Current staff: 5 people

Questions: (Staff-hours and weeks)

1. CV: __ staff-hours
2. CPI: __
3. SV: __ staff-hours
4. SPI: __
5. Cost EAC: a: __ staff-hours b: __ staff-hours
6. Schedule EAC_t: a: __ weeks b: __ weeks

7. CTC: a: __ staff-hours b: __ staff-hours
   Schedule-to-complete: a: __ weeks b: __ weeks
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

ANSWERS

Exercise 1. Staff-days and months

1. CV: -100 staff-days
2. CPI: .82
3. SV: -50 staff-days
4. SPI: .90
5. Cost EAC: a: 1300 staff-days b: 1467 staff-days
6. Schedule EAC_t: a: 12.5 months b: 13.3 months
7. CTC: a: 750 staff-days b: 917 staff-days
   Schedule-to-complete: a: 7.5 months b: 8.3 months
8. TCPI for BAC: 1.15
   TCPI for EAC (*typical*): 0.82
9. RWI: .93
   StSI: .76
   Revised staffing: 6.5 people

Exercise 2. Staff-days and months

1. CV: -7 staff-days
2. CPI: .91
3. SV: -5 staff-days
4. SPI: .94
5. Cost EAC a: 327 staff-days b: 350 staff-days
6. Schedule EAC_t: a: 4.1 months b: 4.3 months
7. CTC a: 245 staff-days b: 268 staff-days
   Schedule-to-complete: a: 3.1 months b: 3.3 months
8. TCPI for BAC 1.03
   TCPI for EAC (*typical*) .91
9. RWI: .98
   StSI: .90
   Revised staffing: 4.5 people

Exercise 3. Staff-hours and days

1. CV: -183 staff-hours
2. CPI: .80
3. SV: -88 staff-hours
4. SPI: .89
5. Cost EAC a: 1991 staff-hours b: 2258 staff-hours
6. Schedule EAC_t: a: 67.6 days b: 72.2 days
7. CTC: a: 1072 staff-hours b: 1339 staff-hours
   Schedule-to-complete: a: 35.6 days b: 40.2 days

8. TCPI for BAC: 1.21
   TCPI for EAC (*typical*): 0.80
9. RWI: .92
   StSI: .74
   Revised staffing: 4.8 people

Exercise 4. Staff-hours and weeks

1. CV: -512 staff-hours
2. CPI: .88
3. SV: -760 staff-hours
4. SPI: .83
5. Cost EAC: a: 7880 staff-hours b: 8407 staff-hours
6. Schedule EAC_t: a: 53 weeks b: 58 weeks
7. CTC: a: 3736 staff-hours b: 4363 staff-hours
   Schedule-to-complete: a: 23.6 weeks: b: 28.6 weeks
8. TCPI for BAC: 1.16
   TCPI for EAC (*typical*): 0.88
9. RWI: .80
   StSI: .70
   Revised staffing: 7.2 people

Now that you have completed all four exercises, **you may answer the first PDU questionnaire (Part 1) for a total of 4 PDUs.**

When you are ready to earn your PDUS:
Please return to www.NewLeafPM.com
- Click on the "White Papers" tab.
- Select "White Paper Power Quizzes for PDU Credit."
- Choose this quiz (Part 1).

Mechanical Tools

For 2 additional PDUs, **solve the four additional exercises (5 through 9)** below and answer **the second PDU questionnaire**.

To be sure your answers are correct:

1. Construct a spreadsheet with all the formulas.
2. Check out your spreadsheet with the first four exercises to be sure your formulas give the correct answers.
3. Use the spreadsheet to generate answers to Exercise 5-8.

Exercise 5

A summary of the facts:

1. Original project cost: 400 staff-days
2. Original project schedule: 4 months
3. Planned value: 80 staff-days at 1 month
4. Actual cost: 80
5. Earned value: 75
6. Current staffing: 4 people

Questions: (Staff-days and months)

1. CV: __ staff-days
2. CPI: __
3. SV: __ staff-days
4. SPI: __
5. Cost EAC: a: __ staff-days b: __ staff-days
6. Schedule EAC_t: a: __ months b: __ months
7. CTC: a: __ staff-days b: __ staff-days
   Schedule-to-complete: a: __ months b: __ months
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

Exercise 6

A summary of the facts:

1. Original project cost: 1800 staff-hours
2. Original project schedule: 60 days
3. Planned value: 800 staff-hours at 30 days
4. Actual cost: 900
5. Earned value: 700
6. Current staff: 3.5

Questions: (Staff-hours and days)

1. CV: __ staff-hours
2. CPI: __
3. SV: __ staff-hours
4. SPI: __
5. Cost EAC: a: __ staff-hours b: __ staff-hours
6. Schedule EAC_t: a: __ days b: __ days
7. CTC: a: __ staff-hours b: __ staff-hours
   Schedule-to-complete: a: __ days b: __ days
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

Exercise 7

A summary of the facts:

1. Original project cost: 7400 staff-hours
2. Original project schedule: 48 weeks
3. Planned value: 4400 staff-hours at 30 weeks
4. Actual cost: 4100
5. Earned value: 3600
6. Current staff: 5 people

Questions: (Staff-hours and weeks)

1. CV: __ staff-hours
2. CPI: __
3. SV: __ staff-hours
4. SPI: __
5. Cost EAC: a: __ staff-hours b: __ staff-hours
6. Schedule EAC_t: a: __ weeks b: __ weeks
7. CTC: a: __ staff-hours b: __ staff-hours
   Schedule-to-complete: a: __ weeks b: __ weeks
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

Exercise 8

A summary of the facts:

1. Original project cost: 7000 staff-hours
2. Original project schedule: 48 weeks
3. Planned value: 4000 staff-hours at 30 weeks
4. Actual cost: 4100
5. Earned value: 3900
6. Current staff: 5 people

Questions: (Staff-hours and weeks)

1. CV: __ staff-hours
2. CPI: __
3. SV: __ staff-hours
4. SPI: __
5. Cost EAC: a: __ staff-hours b: __ staff-hours
6. Schedule EAC_t: a: __ weeks b: __ weeks
7. CTC: a: __ staff-hours b: __ staff-hours
   Schedule-to-complete: a: __ weeks b: __ weeks
8. TCPI for BAC: ___
   TCPI for EAC (*typical*): ___
9. RWI: __
   StSI: __
   Revised staffing: __ people

For 2 additional PDUs, answer the second PDU questionnaire (Part 2).

When you are ready to earn your PDUS:
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Further Reading

When you have mastered the calculations that show you the earned value analysis for your project, you may want to read Mark Durrenberger's *An Earned Value Tutorial* to see a bit more about what it's like to use these tools on a real project.

If you would like more details on the RWI and the StSI, read John Nevison's *The Remaining Work Index (RWI) and the Staffing-to-Schedule Index (StSI): How to use two new indexes to adjust staffing and make your schedule.*

Both articles are available on New Leaf's web site (www. NewLeafPM.com) and both can be studied to earn additional PDUs.

About the Author

John M. (Jack) Nevison, PMP is the author of six books and numerous articles on computing and management. During the course of his business career, Nevison has built and sold two businesses, managed projects, managed project managers, and served as both an internal and external consultant to Fortune 100 companies. He is past president of the Mass Bay Chapter of the Project Management Institute (PMI®), a past president of the Greater Boston Chapter of the Association for Computing Machinery (ACM), a certified Project Management Professional (PMP), and a Phi Beta Kappa graduate of Dartmouth.

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