An Integrated Exercise to Teach Earned Value Management

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Earned Value Management (EVM) provides the basis for assessing work progress against a baseline plan, relates technical, time and cost performance, and gives managers a summary of effective decision-making. It is a useful technique for objectively measuring project performance and progress. This paper discusses developing and implementing an integrated example problem that can teach students the effective use of EVM techniques. This approach is designed to deepen student understanding of the basic concepts of EVM, from initial project planning through execution, including data analysis techniques and baseline revisions. Successful implementation of EVM requires an understanding of important project elements, including requirements, schedule, budget, assumptions, constraints, and objectives, and therefore reinforces many of the key project management concepts students study in our courses. Implementing the integrated example aims to inspire an appreciation for the earned value concept and emphasize how performance measurement techniques can be a valuable management tool for analyzing cost and schedule performance.

Keywords: earned value management, scheduling, budgeting

INTRODUCTION

Translating customer requirements into work activities, developing an effective schedule and budget plan, and monitoring and controlling project execution is a key aspects of project management. Project managers are challenged with taking activities that need to be performed in a certain sequence and completed within a specified time and cost (Agyei, 2015). An effective project schedule and budget provide the framework for the assignment of resources and sequencing of activities to be performed to carry out the plan of work Arcuri, et.al., 2007). The ability to create resource estimates and build project schedules and monitor, control and report progress is an essential multi-disciplinary skill, and the importance of engineering practitioners and managers possessing these skills continues to rise (Hildreth, et.al., 2005). As the project progresses, project managers and their customers tend to learn additional information that often leads to scope changes involving revising activity completion times by applying other resources. The complexity of schedule control and resource allocation grows significantly as changes to scope and activity

durations occur. Implementation of EVM techniques can improve visibility into the program cost, schedule, and other key performance indicators (Heinlein et.al., 2012).

Schedule development, resource management, project control, and reporting are taught as part of The Citadel's undergraduate and graduate technical project management courses, which explore the principles and applications of project scope, project requirements, and work breakdown structures (WBS); development and control of schedules, risk management, project execution, and closeout. The students are introduced to EVM as a management technique that will provide an early warning of performance problems. EVM is a critical technique in that it measures the project performance and progress by integrating the three most important elements in a project: cost, schedule, and performance (Naeni, et al., 2014). The goal of introducing students to EVM was to provide them with a technique for measuring and evaluating a project's progress and performance. EVM accomplishes its analysis by estimating the time and cost of completing a project based on its actual cost and time to complete activities from any point in the project.

However, test results and end-of-course feedback reflected that while the students were learning the mechanics of creating a project schedule and budget, they did not fully grasp how to monitor and control execution and report cost and schedule progress. In response, the faculty brainstormed ideas to incorporate into the instruction to better teach students how to apply EVM. An instructional goal was to develop an integrated exercise to demonstrate and tie together key concepts through a comprehensive example project. The authors developed an integrated spreadsheet model that was easy to use and provided a natural interface for model building (Baker, et al., 2007).

Description

This paper discusses the development of an integrated spreadsheet exercise to teach students how to monitor and report cost and schedule performance of technical projects using Earned Value Management techniques. The instruction complements several existing courses (PMGT 401, PMGT 650, PMGT 651, and PMGT 653). We chose to build a spreadsheet-based exercise because most students already have spreadsheet programs on their computers and are likely to use spreadsheets in future projects, careers, and personal life. Spreadsheet programs are flexible, familiar, and relatively easy to use [6]. The EVM techniques we will discuss in this paper are implemented using the standard Excel functions. We introduce students to cost and schedule performance monitoring and reporting using a simple project involving the relocation of a work facility. At the start of the exercise, students were provided a project scenario for relocating a work facility, activity list, and precedence relationships in the instructions. This assignment is designed to give students exposure to using EVM to monitor, control, and report costs and schedule for a new facility their organization will be moving into within the next few weeks. The project network diagram developed from the activity list and precedence relationships is shown in Figure 1.

FIGURE 1
NETWORK DIAGRAM FOR THE FACILITY RELOCATION ACTIVITIES
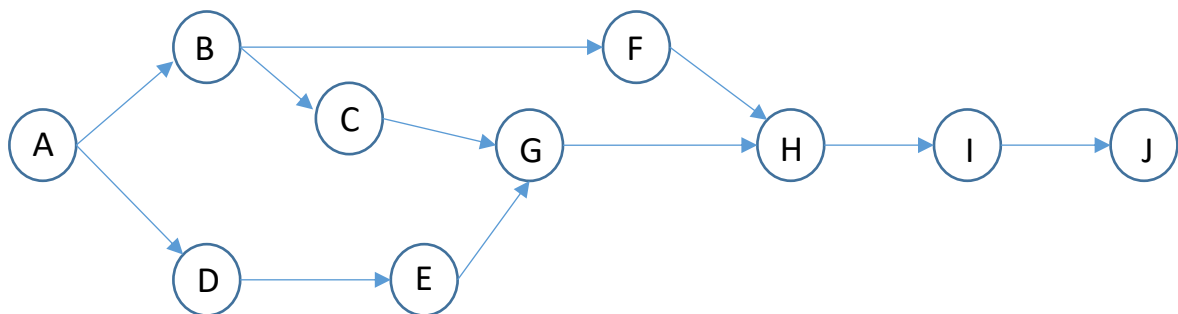
Students are provided with the planned and actual times and costs for the Facility Relocation Project. Using the EVM spreadsheet template, students fill the role of Project Manager. They are asked to enter the planned and actual data and then analyze and report to the CEO the status of the New Facility Project they are heading up. Using the following exercise information, the students are asked to conduct and evaluate the EVM analysis and report the status of the project to include:

1. Comparison of original baseline cost and schedule estimates to the actuals
2. Calculate and interpret the following:
   a. Estimate to complete
   b. Interpretation of performance indices
   c. Calculate and Interpret cost and schedule variances
   d. Calculate and interpret cost and schedule performance indices
3. Report to the CEO the status of the project in a well-written paragraph

TABLE 1
THE FACILITY RELOCATION PROJECT ACTIVITIES

Activity	Work Package	Task	Planned Working Weeks	Predecessors				Planned Cost	Actual Working Weeks	Actual Cost	% Progress
		Project Start Date	1/2/2020	P1	P2	P3			1/2/2020		
S	0	Start	0						0		100%
A	1	Locate Facility	2					$ 4,000.00	3	$ 6,000.00	100%
B	2	Order Furniture	1	A				$20,000.00	2	$35,000.00	100%
C	3	Interview	4					$ 3,000.00	3	$ 6,000.00	90%
D	4	Hire & Train	2	C				$16,000.00	3	$24,000.00	90%
E	5	Remodel	3	A				$60,000.00	3	$75,000.00	95%
F	6	Furniture Setup	1	B				$15,000.00	2	$18,000.00	100%
G	7	Inspect	1	D	E	F		$ 1,500.00	2	$ 3,000.00	85%
H	8	Occupy	1	G				$ 2,000.00	1	$ 2,400.00	80%
I	9	Start Operations	1	H				$ 1,500.00	1	$ 1,000.00	80%

Enter data provided in the assignment instructions into the yellow shaded cells on each spreadsheet tab to start your analysis.

Info to Date | Plan | EV | AC | Report

The "Information to Date" tab in the exercise spreadsheet has yellow shaded cells identifying where the students should enter the initial information. The next step in the exercise involves creating a budget for the planned work, which requires students to review the dependencies, and order of precedence for the activity list and allocate the planned costs for each activity according to the duration. Students are advised to allocate budget percentages equally over the duration. For example, there are no dependencies for activity A with a planned duration of two weeks, so one-half of the planned costs are allocated in week one and the remaining half in week two. Table 2 shows the correctly allocated planned costs for the exercise scenario.

TABLE 2
PLANNED COST ALLOCATION

Activity	Work Package	Task	Planned Working Weeks	Budgeted Cost	1	2	3	4	5	6	7	8	9	10	11	12
S	0	Start	0													
A	1	Locate Facility	2	$ 4,000	$2,000	$2,000										
B	2	Order Furniture	1	$ 20,000			$20,000									
C	3	Interview	4	$ 3,000	$ 750	$ 750	$ 750	$ 750								
D	4	Hire & Train	2	$ 16,000					$ 8,000	$ 8,000						
E	5	Remodel	3	$ 60,000			$20,000	$20,000	$ 20,000							
F	6	Furniture Setup	1	$ 15,000				$15,000								
G	7	Inspect	1	$ 1,500							$ 1,500					
H	8	Occupy	1	$ 2,000								$ 2,000				
I	9	Start Operations	1	$ 1,500									$ 1,500			
				$123,000												
		Total Budgeted Cost			$ 2,750	$ 2,750	$40,750	$35,750	$ 28,000	$ 8,000	$ 1,500	$ 2,000	$ 1,500	$ -	$ -	$ -
		Cumuative PV			$ 2,750	$ 5,500	$46,250	$82,000	$110,000	$118,000	$119,500	$121,500	$123,000	$123,000	$123,000	$123,000

Info to Date | **Plan** | EV | AC | Report

The next step in the exercise requires the students to report the earned value of the work completed to date against the planned work. Students follow the same process of equally dividing the percentage of work completed over the actual task duration of the work performed. Table 3 shows the correct earned value for the exercise scenario. The highest percentage of work completed is carried to the end of the project. For example, if Activity C incurred 3 weeks of completed work and achieved 90% completion, students report 90% completion for each remaining week of the project, as shown in Table 3. This is done to support creating the EV plotting.

TABLE 3
EARNED VALUE (EV) ALLOCATION

			Cumulative EV												
Activity	Work Package	Task	Budgeted Cost	1	2	3	4	5	6	7	8	9	10	11	12
S	0	Start	$ -												
A	1	Locate Facility	$ 4,000.00	33%	67%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
B	2	Order Furniture	$ 20,000.00				50%	100%	100%	100%	100%	100%	100%	100%	100%
C	3	Interview	$ 3,000.00	30%	60%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
D	4	Hire & Train	$ 16,000.00				30%	60%	90%	90%	90%	90%	90%	90%	90%
E	5	Remodel	$ 60,000.00				32%	64%	95%	95%	95%	95%	95%	95%	95%
F	6	Furniture Setup	$ 15,000.00						50%	100%	100%	100%	100%	100%	100%
G	7	Inspect	$ 1,500.00									43%	85%	85%	85%
H	8	Occupy	$ 2,000.00										80%	80%	80%
I	9	Start Operations	$ 1,500.00											100%	80%
		Cumulative EV		$ 2,233	$ 4,466	$ 6,700	$40,500	$74,700	$105,600	$113,100	$113,738	$114,375	$115,975	$117,475	$ 117,175

Info to Date | Plan | **EV** | AC | Report

The next step is for the students to report the actual costs of work completed for each activity to date. Again, costs are equally divided over the duration Table 4 shows the correctly allocated actual costs for the exercise scenario.

TABLE 4
ACTUAL COST (AC) ALLOCATION

Activity	Work Package	Task	Actual Cost	1	2	3	4	5	6	7	8	9	10	11	12
S	0	Start	$ -												
A	1	Locate Facility	$ 6,000.00	$2,000	$2,000	$2,000									
B	2	Order Furniture	$35,000.00				$17,500	$17,500							
C	3	Interview	$ 6,000.00	$2,000	$2,000	$2,000									
D	4	Hire & Train	$24,000.00				$ 8,000	$ 8,000	$ 8,000						
E	5	Remodel	$75,000.00				$25,000	$25,000	$25,000						
F	6	Furniture Setup	$18,000.00						$ 9,000	$ 9,000					
G	7	Inspect	$ 3,000.00								$ 1,500	$ 1,500			
H	8	Occupy	$ 2,400.00										$ 2,400		
I	9	Start Operations	$ 1,000.00											$ 1,000	
			Culmative AC	$ 4,000	$ 8,000	$ 12,000	$ 62,500	$ 113,000	$ 155,000	$164,000	$165,500	$167,000	$169,400	$170,400	$170,400

Info to Date	Plan	EV	**AC**	Report	⊕

At this point, students have captured the planned and actual accrued costs and value completions and are ready to begin the analysis phase of the exercise. The Report tab of the exercise spreadsheet pulls data from the first four tabs of the spreadsheet to calculate and display the key EVM metrics we cover in the course and displayed in Table 5.

TABLE 5
KEY EVM METRICS AND INDICES

| Actual Cost and Earned Value	1	2	3	4	5	6	7	8	9	10	11	12
Actual Cost (AC)	$ 4,000	$ 8,000	$ 12,000	$ 62,500	$113,000	$155,000	$164,000	$165,500	$167,000	$169,400	$170,400	$170,400
Earned Value (EV)	$ 2,233	$ 4,466	$ 6,700	$ 40,500	$ 74,700	$105,600	$113,100	$113,738	$114,375	$115,975	$117,475	$117,175
Planned Value (PV)	$ 2,750	$ 5,500	$ 46,250	$ 82,000	$110,000	$118,000	$119,500	$121,500	$123,000	$123,000	$123,000	$123,000
Performance Metrics												
Cost Variance (CV = EV - AC)	$ (1,767)	$ (3,534)	$ (5,300)	$ (22,000)	$ (38,300)	$ (49,400)	$ (50,900)	$ (51,763)	$ (52,625)	$ (53,425)	$ (52,925)	$ (53,225)
Schedule Variance (SV = EV - PV)	$ (517)	$ (1,034)	$ (39,550)	$ (41,500)	$ (35,300)	$ (12,400)	$ (6,400)	$ (7,763)	$ (8,625)	$ (7,025)	$ (5,525)	$ (5,825)
Cost Performance Index (CPI = EV/AC)	1	1	1	1	1	1	1	1	1	1	1	1
Schedule Performance Index (SPI = EV/PV)	1	1	0	0	1	1	1	1	1	1	1	1
Estimated Cost at Completion (EAC)	$220,312	$220,312	$220,299	$189,815	$186,064	$180,540	$178,355	$178,978	$179,593	$179,661	$178,414	$178,871

Students utilize the data from Table 5 and Table 6 to calculate the Estimate to Complete (ETC), Cost and Schedule Variances, and the Cost and Schedule Performance Indices. The final part of the exercise requires the students to evaluate the earned value information they have collected, interpret the data, and then develop a concise project summary report on the current progress to date of the project to be briefed to the CEO.

TABLE 6
EVM VARIANCES AND INDICES

Work Package	BCWS Planned Value	ACWP Actual Cost	% Progress	BCWP Earned Value
0	$ -	0	100%	$ -
1	$ 4,000.00	6000	100%	$ 4,000.00
2	$ 20,000.00	35000	100%	$ 20,000.00
3	$ 3,000.00	6000	90%	$ 2,700.00
4	$ 16,000.00	24000	90%	$ 14,400.00
5	$ 60,000.00	75000	95%	$ 57,000.00
6	$ 15,000.00	18000	100%	$ 15,000.00
7	$ 1,500.00	3000	85%	$ 1,275.00
8	$ 2,000.00	2400	80%	$ 1,600.00
9	$ 1,500.00	1000	80%	$ 1,200.00
	$ 123,000.00	$170,400.00		$ 117,175.00

ETC = (PV-EV)	$ 5,825.00
PV	$ 123,000.00
AC	$ 170,400.00
EV	$ 117,175.00

Cost Variance (CV = EV - AC)	$(53,225.00)
Cost Performance Index (CPI = EV/AC)	0.6876
Schedule Variance (SV = EV - PV)	$ (5,825.00)
Schedule Performance Index (SPI = EV/PV)	0.9526

The spreadsheet will automatically generate a chart showing the variances between planned value, earned value, and the project's actual cost. The cumulative EVM chart combined with the EVM calculations provides a way to display cost and schedule conditions on the project visually. It can easily support decision analysis to determine actions contributing to schedule and cost variances.

FIGURE 2
PROJECT EARNED VALUE
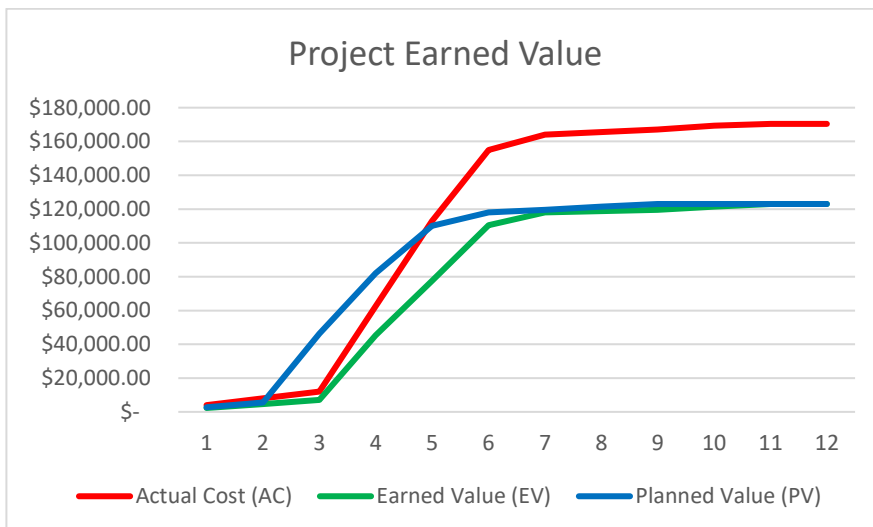
USAGE

The integrated spreadsheet exercise presented in this paper is useful for professors teaching cost and schedule control. Spreadsheets are readily available to students and faculty, and our integrated example uses standard Excel functions without macros. The model is easily modified to expand additional tasks and incorporate more complex examples by using a few copy commands. While students are informed of the math behind the calculations, the spreadsheet only requires the student to input required data, and the model is generally set up to auto-calculate and produce the output and charts for analysis. This allows students to concentrate on properly describing the problem and analyzing the solution without having to perform tedious calculations. We have used our model in undergraduate and graduate introductory project management courses to reinforce key concepts and broaden student understanding of monitoring and controlling project costs and schedules. The responses from students have been favorable as most students like the ease of use and do not have to deal with learning another software program. They also state that the integrated exercises make it easier for them to understand the relationships between planned versus actual cost and scheduled performance. Before the exercise, the faculty covered cost and schedule control as separate lecture topics. The integrated exercise has allowed us to spend less time on each individual topic and more time demonstrating how these topics overlap and influence each other through practical application. For future research, we plan to perform before and after analysis of grades for the exercise to measure any improvement in student performance after completing the integrated exercise problem.

CONCLUSIONS

Integrated spreadsheet models are an effective means of enforcing key project management and decision-making skills in students. Automating many analytical techniques allows students to focus on understanding the concepts and applying that understanding to analyze potential solutions to meet customer needs. The integrated exercise can also show the students how to pinpoint the part of the project that, if delayed beyond the allotted time, would increase the project's completion time. It further assists in allocating resources and thus helps to make the project's total cost a minimum by finding the optimum balance between various costs and the time involved. Using an integrated spreadsheet example, this paper describes one approach to expanding student comprehension of cost and schedule control. As student feedback on using the example has been positive, we intend to continue its use and expand the scenario to include a more complex scenario.

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