Review of Work Progress by Earned Value Analysis

Mithun Murali M
UG Student
Department of Civil Engg
TKMCE
Kollam, India

Prof. Mohamed Asim
Associate Professor
Department of Civil Engg
TKMCE
Kollam, India

***Abstract*— Project control tools are commonly used in the construction industry. Unfortunately, many projects run over budget and behind schedule, which suggests that there is something wrong in our project control system. The earned-value method (EVM) is a project control technique that provides a quantitative measure of work performance. It is considered the most advanced technique for integration of schedule and cost. This paper attempts to evaluate work progress in a quantitative manner. Through Earned Value Analysis project cost and time at completion is forecasted and also the performance needed to bring the project back to planned cost and time is also calculated**

I. INTRODUCTION

A successful project is one that is completed in time, that is within budget, and that satisfies the appropriate technical and safety standards. The successful delivery of a project depends on the proper management of the project. A well planned project may be a failure if it is not managed properly. It is here that we recognize the importance of Project Management. It is the application of knowledge, skills, tools and techniques to the project activities to meet or exceed the needs and expectations of stakeholders. Although- several systems and techniques are available to support project management efforts, the task of tracking costs and durations of a project is still difficult and challenging. This difficulty is perhaps due to the fact that the three basic categories of project data (i.e., cost, scheduling, and progress) are intimately interrelated, and they are also time dependent. This makes independent tracking of any one category of little or no value unless it is integrated with the other two. This shows the need for a practical quantitative method for measuring work progress, which would eliminate a major cause for this difficulty.

The objective is to present an outline for a comprehensive and practical system to measure work progress on a construction project objectively. The proposed system employs two principles. The Construction schedule bar chart is used to integrate cost and scheduling data, and the earned value concept is used to serve as the yardstick for measuring progress.

Earned Value Management (EVM) is a project management technique for measuring project progress in an objective manner. EVM has the ability to combine measurements of scope, schedule, and cost in a single integrated system. When properly applied, EVM provides an early warning of performance problems. Additionally, EVM promises to improve the definition of project scope, prevent scope creep, communicate objective progress to stakeholders, and keep the project team focused on achieving progress.

II. KEY COMPONENTS OF EVM

EVM uses cost as the common measure of project cost and schedule performance. It allows the measurement of cost in currency, hours, worker-days, or any other similar quantity that can be used as a common measurement of the values associated with project work. EVM uses the following project parameters to evaluate project performance.

A. Planned value

The approved budget for the work scheduled to be completed by a specified date; also referred to as the budgeted cost of work scheduled (BCWS). The total PV of a task is equal to the task's budget at completion (BAC) – the total amount budgeted for the task.

B. Earned value

The approved budget for the work actually completed by the specified date; also referred to as budgeted cost of work performed (BCWP).

C. Actual cost

The costs actually incurred for the work completed by specified date; also referred to as actual cost of work performed (ACWP).

D. Schedule variance (SV)

The difference between the amounts budgeted for the work you actually did and for the work you planned to do. The SV shows whether and by how much your work is ahead of or behind your approved schedule.

E. Cost variance (CV)

The difference between the amount budgeted and the amount actually spent for the work performed. The CV shows whether and by how much you are under or over your approved budget.

F. Schedule performance index (SPI)

The ratio of the approved budget for the work performed to the approved budget for the work planned. The SPI reflects the relative amount the project is ahead of or behind schedule, sometimes referred to as the project's schedule efficiency.

G. Cost performance index (CPI)

The ratio of the approved budget for the work performed to what you actually spent for the work. The CPI reflects the relative value of work done compared to the amount paid for it, sometimes referred to as the project's cost efficiency.

H. Time estimate at completion (TEAC)

Using the assumption that past schedule performance is a good predictor of future schedule performance, and that schedule efficiencies, or inefficiencies, observed to date will prevail to completion, then the Time Estimate at Completion (TEAC) is the sum of the cumulative actual time plus the original scheduled time for the remaining work modified by the cumulative schedule performance index (SPI).

I. Estimate at completion (EAC)

EAC is the manager's projection of total cost of the project at completion.

J. Estimate to complete (ETC)

The estimate of the amount of funds required to complete all work still remaining to be done on the task.

I. Variance at completion (VAC)

Variance at completion shows the variance of the total cost of the work and expected cost.

III. EVM IMPLEMENTATION

There are many more small and simple projects than there are large and complex ones, yet historically only the largest and most complex have enjoyed the benefits of EVM. Still, lightweight implementations of EVM are achievable by any person who has basic spreadsheet skills. In fact, spreadsheet implementations are an excellent way to learn basic EVM skills.

The first step is to define the work. This is typically done in a hierarchical arrangement called a work breakdown structure (WBS) although the simplest projects may use a simple list of tasks. In either case, it is important that the WBS or list be comprehensive. It is also important that each element be mutually exclusive, so that work is easily categorized in one and only one element of work. The most detailed elements of a WBS hierarchy (or the items in a list) are called terminal elements of work.

The second step is to assign a value, called planned value (PV), to each terminal element. For large projects, PV is almost always an allocation of the total project budget, and may be in units of currency (e.g. Dollars or Euros) or in labor hours, or both. However, in very simple projects, each terminal element may be assigned a weighted "point value" which might not be a budget number. Assigning weighted values and achieving consensus on all PV quantities yields an important benefit of EVM, because it exposes misunderstandings and miscommunications about the scope of the project, and resolving these differences should always occur as early as possible. Some terminal elements cannot be known (planned) in great detail in advance, and that is expected, because they can be further refined at a later time.

The third step is to define "earning rules" for each terminal element. The simplest method is to apply just one earning rule, such as the 0/100 rule, to all terminal elements. Using the 0/100 rule, no credit is earned for an element of work until it is finished. A related rule is called the 50/50 rule, which means 50% credit is earned when an element of work is started, and the remaining 50% is earned upon completion. Other fixed earning rules such as a 25/75 rule or 20/80 rule are gaining favor, since they assign more weight to finishing work than for starting it, but they also motivate the project team to identify when an element of work is started, which can improve awareness of work-in-progress. These simple earning rules work well for small or simple projects because generally each terminal element tends to be fairly short in duration.

These initial three steps define the minimal amount of planning for simplified EVM. The final step is to execute the project according to the plan and measure forward progress. When terminal elements are started and/or finished, EV is accumulated according to the earning rule. This is typically done at regular intervals (e.g. weekly or monthly).

In many projects, schedule performance (completing the work on time) is equal in importance to technical performance. EVM skill can be very helpful in managing the schedule performance. The project manager may employ a critical path or critical chain to build a project schedule model. The project manager must define the work comprehensively, typically in a WBS hierarchy. He/she will construct a project schedule model that describes the precedence links between elements of work.

In addition to managing technical and schedule performance, large and complex projects require that cost performance is monitored and reviewed at regular intervals. To measure cost performance, planned value (or BCWS - Budgeted Cost of Work Scheduled) and earned value (or BCWP - Budgeted Cost of Work Performed) must be in units of currency (the same units that actual costs are measured).

IV. PROJECT PERFORMANCE TRACKING

The project taken for the study was a commercial building in Prathibha Jn, Kollam, Kerala. The total estimated amount for the entire project was Rs. 46.35 million. Our work was limited to the project tracking for 6 months ie; from September 2014 to February 2015. The estimated amount of the work from January 2014 to February 2015 was Rs 2,12,84,000 which includes skeleton work only. The concerned part of project was scheduled for 20 months with planned start date on 16th Jan, 2014, ie, 14 months for skeleton work and 6 months for other finishing works. Since it is water logged area, each floor is constructed in two halves. The details of entire project are given below.

Total built-up area = 38628.4 Sq.ft.
Type of Building = Commercial Building
Number of floors = Cellar + G + 3
Total estimated construction cost = Rs. 46.35 million
Total cost per Sq.ft. = Rs. 1200
Planned start date = 16th Jan 2014
Completion period = 20 months

A. Photos taken during the construction phase

B. Scheduling

TABLE1. SCHEDULED DURATION AND ESTIMATED COST

Activities	*Scheduled duration (days)*	*Total cost for individual activities (Rs)*
Cellar Floor		
PCC And Pile work	47	40,15,868
Retaining wall	28	12,60,480
Column work	48	4,95,333
Main stair	12	45,046
Beam and Roof slab	39	24,01,029
Ground Floor		
Column work	48	4,95,333
Fire and Main stair	32	1,58,974
Beam and Roof slab	37	26,11,597
First Floor		
Column work	48	4,95,333
Fire and Main stair	32	1,58,974
Beam and Roof slab	37	26,11,597
Second Floor		
Column work	48	4,95,333
Fire and Main stair	32	1,58,974
Beam and Roof slab	37	26,11,597
Third Floor		
Column work	48	4,95,333
Fire and Main stair	32	1,58,974
Beam and Roof slab	37	26,11,597
Budget at completion		2,12,84,000
Masonry and other Finishing works	198	2,50,70,000

TABLE 2. COMPARISON OF SCHEDULE

Activities	*Planned schedule*	*Actual schedule*
PCC and Pile work	Jan 16-Mar 04	Up to Sep
Column @ Cellar Ist half	Mar 05-Mar 08	
Roof slab and Roof beam @ Cellar Ist half	Mar 29-Apr 16	
Column @ GF Ist half	Apr 17-May 10	
Roof slab and Roof beam @ GF Ist half	May 11-May 28	Sep 12-Oct 04
Fire stair @ GF	May 18-May 28	Sep 17-Oct 04
Retaining wall	May 29-June 26	Oct 04-Oct 29
Column @ FF Ist half	June 27- July 20	Oct 27-Nov 16
Column @ Cellar IInd half	July 05-July 28	Nov 16-Dec 17
Roof slab and Roof beam @ Cellar IInd half	July 29- Aug 17	Dec 22-Jan 14
Main stair @ Cellar	Aug 06-Aug 17	Dec 28-Jan 14
Roof slab and Roof beam @ FF Ist half	Aug 11-Aug 29	Jan 15-Jan 28
Fire stair @ FF	Aug 18-Aug 29	Jan 18-Jan 28
Column @ GF IInd half	Aug 18-Sep 10	Jan 19-Feb 01
Roof slab and Roof beam @ GF IInd half	Sep 11-Sep 29	Feb 02-Feb 16
Main stair @ GF	Sep 18-Sep 29	Feb 08-Feb 16
Column @ SF Ist half	Sep 15-Oct 08	Jan 29-Feb 20
Column @ FF IInd half	Sep 30-Oct 23	Feb 20-Mar 04
Roof slab and Roof beam @ SF Ist half	Oct 09-Oct 27	Feb 21- Mar 06

TABLE 3. COMPARISON OF COST

Activities	*Planned cost (Rs)*	*Actual cost (Rs)*
PCC and Pile work	40,15,868	66,00,000
Column @ Cellar Ist half	2,47,666	
Roof slab and Roof beam @ Cellar Ist half	12,00,514	
Column @ GF Ist half	2,47,666	
Roof slab and Roof beam @ GF Ist half	13,05,798	16,35,000
Fire stair @ GF	1,13,928	1,42,000
Retaining wall	12,60,480	17,20,000
Column @ FF Ist half	2,47,666	3,12,500
Column @ Cellar IInd half	2,47,666	3,23,000
Roof slab and Roof beam @ Cellar IInd half	12,00,514	16,35,000
Main stair @ Cellar	45,046	88,000
Roof slab and Roof beam @ FF Ist half	13,05,798	17,20,000
Fire stair @ FF	1,13,928	1,44,000
Column @ GF IInd half	2,47,666	3,14,300
Roof slab and Roof beam @ GF IInd half	13,05,798	15,87,000
Main stair @ GF	45,046	78,500
Column @ SF Ist half	2,47,666	3,19,000
Column @ FF IInd half	2,47,666	3,20,500
Roof slab and Roof beam @ SF Ist half	13,05,798	16,45,000

TABLE 4. COMPARISON OF PERCENTAGE COMPLETION OF WORK

Month	*Cumulative planned % of completion*	*Cumulative actual % work completed*
Jan 2014	6	29
Feb	16	
Mar	21	
Apr	28	
May	32	
Jun	37	
Jul	46	
Aug	55	
Sep	64	32
Oct	73	37
Nov	85	44
Dec	92	47
Jan 2015	98	57
Feb	100	71

V. EARNED VALUE ANALYSIS

A. EVM Calculations

The earned value analysis is carried out for the months, September 2014 – February 2015.

Planned Value (PV) = Planned % completion x BAC

Earned Value (EV) = Actual % work completed x BAC

BAC = 21284000

TABLE 5. CUMULATIVE PV, EV, AND AC

Month	*Planned value*	*Earned value*	*Actual cost*
Upto Sep 2014	0.55 x 21284000 = 1,17,06,200	0.29 x 21284000 = 61,72,360	66,00,000
Sep	0.64 x 21284000 = 1,36,21,760	0.32 x 21284000 = 68,10,880	83,77,000
Oct	0.73 x 21284000 = 1,55,37,320	0.37 x 21284000 = 78,75,080	1,01,59,500
Nov	0.85 x 21284000 = 1,80,91,400	0.44 x 21284000 = 93,64,960	1,06,03,300
Dec	0.92 x 21284000 = 1,95,81,280	0.47 x 21284000 = 1,00,03,480	1,13,06,833
Jan 2015	0.98 x 21284000 = 2,08,58,320	0.57 x 21284000 = 1,21,31,880	1,46,33,800
Feb	1 x 21284000 = 2,12,84,000	0.71 x 21284000 = 1,51,11,640	1,76,97,200

In Table 5, cumulative planned value, cumulative earned value and cumulative actual cost of the project for a period of 6-month duration and budget at completion for the project of 14-month duration are tabulated from the collected data and the values are given as:

1. Planned Value (BCWS) = Rs 2,12,84,000
2. Earned Value (BCWP) = Rs 1,51,11,640
3. Actual Cost (ACWP) = Rs 1,76,97,200
4. Budget at completion (BAC) = Rs 2,12,84,000

TABLE 6. SCHEDULE ANALYSIS AND FORECASTING

To calculate	*Formula*	*Value*	*Project management questions*	*Interpretation*
Schedule variance (SV)	SV = EV-PV	-61.72 Lakhs	Are we ahead or behind of schedule?	Behind schedule
Schedule performance index (SPI)	SPI = $\frac{EV}{PV}$	0.71	How efficiently are we using time?	Behind schedule
Time estimate at completion (TEAC)	$\frac{(BAC/SPI)}{(BAC/Month)}$	20 Months	When are we likely to finish work?	Not on schedule

TABLE 7. COST ANALYSIS AND FORECASTING

To calculate	*Formula*	*Value*	*Project management questions*	*Interpretation*
Cost variance (CV)	CV = EV-AC	-25.85 Lakhs	Are we under or over our budget?	Over budget
Cost performance index (CPI)	CPI = EV / AC	0.85	How efficiently are we using resources?	Over budget
Estimate at completion (EAC)	EAC = BAC / CPI	250.40 Lakhs	What is the project likely to cost?	Assumption: Current performance trend continue
Variance at completion (VAC)	VAC = BAC-EAC	-37.56 Lakhs	Are we under or over budget?	Over budget
Estimate to complete (ETC)	(BAC-EV) / CPI	72.61 Lakhs	What will be the remaining work cost?	Assumption: Current performance trend continue

B. Performance Graphs

The performance graph for the project is shown

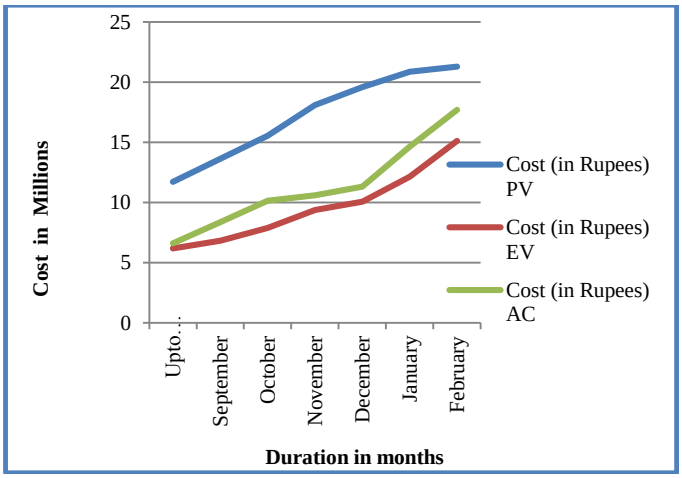

Fig. 1. Cumulative Planned Value, Earned Value, and Actual Cost for the Project.

Figure 1 shows the S-Curve for cumulative planned value, earned value and actual cost of the project for a period of 6 months. The chart shows the 6-month interval from Sep 2014 to Feb 2015 and it is found that the EV line is below the PV or AC line, which means there are problems in those areas. From Figure, it is clear that the earned value line is below the planned value line, which indicates that the work has not been accomplished as per the planned value. From Figure, it is also clear that the earned value line is below the actual cost line, which indicates that the work has been going as a cost over run.

VI. RESULTS AND DISCUSSIONS

It is clear that: The project has an unfavourable schedule variance of -61.72 that means the project is behind schedule. An SPI of 0.71 would tell that the project is progressing at 71% of the rate originally planned. SPI indicates the rate at which the project is progressing. The originally estimated completion time for the project was 14 months for skeleton work. Here we found that if work continuous at the current rate, the project will take 6 months longer than what was originally planned as time estimate for completion is now 20 months for skeleton work. So it takes 26 months for the entire project which includes 6 months for the finishing works.

The project has an unfavourable cost variance of -25.85 which means the project is over budget. A CPI of 0.85 would tell that the project is currently running over budget by 15% that is for each rupee we spend, we are getting a value of rupee 0.85.

Estimate at completion shows that the expected total cost of the project at completion is based on the performance of the data date 21284000 Rs divided by 0.85 is 250.40 lakhs. Therefore, EAC is 250.40 lakhs for skeleton work. In other words, since the project is getting only 0.85 rupee out of every rupee, the project will cost Rs. 250.40 lakhs instead of Rs. 212.84 lakhs that were planned. So a total cost of Rs. 501.1 lakhs are expected instead of Rs.463.5 lakhs for the entire project which includes Rs.250.7 lakhs for finishing works.

Variance at completion shows the variance of the total cost of the work and expected cost. Here it is -37.56. That means at this status date, the project is over budget by Rs. 37.56 lakhs. Estimate to complete shows the expected cost required for finishing all the remaining work, here it is Rs.72.61 lakhs. This amount is needed to complete the work.

VII. CONCLUSION

Through this project work, the effectiveness of EVM technique in assessing the project performance during the construction phase is studied. As the project had already completed about 71%. From the CPI and SPI values found out the project cost and time at completion is forecasted and also the performance needed to bring the project back to the planned / scheduled cost and time is also calculated. Due to the variation in the cost of the material, labour, equipment hiring, other overhead cost, and since the site is water logged the actual cost of work done is higher than what is expected. This cause the CPI value to be less than 1. Thus a cost over-run had occurred in the project, till monitored. Also as the project was a commercial building, maintaining the scheduled duration is given more importance than cost over-run. To keep the project on schedule the working time was adjusted to 10 hrs per day and Sundays also kept as a working day. Hence, from the study it is clear that EVM is an effective tool in the hands of a project manager to keep the project within the budgeted amount and time, if properly utilized.

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