

EARNED VALUE – TECHNIQUE USED TO EVALUATE COST AND SCHEDULE EFFICIENCY OF CONSTRUCTION PROJECTS

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Abstract:

Project management is the application of knowledge, skills, tools and techniques to get the job done on time, within budget, according to specifications and with customer satisfaction. The paper shortly describes technique used to objectively evaluate cost and schedule efficiency of construction projects. Earned Value technique uses three data sources: 1. the budget cost of work scheduled (BCWS), 2. the actual cost of work performed (ACWP) and 3. the earned value (EV) or budget cost of work performed. Using schedule variance (the difference between EV and BCWS) and cost variance (the difference between EV and ACWP) we can qualify cost and schedule efficiency of projects, and after that determine reasons and take certain steps and corrective actions in order to finish the project according to planned costs and schedule.

Keywords: earned value management, budget cost of work scheduled (BCWS), actual cost of work performed (ACWP), earned value (EV) or budget cost of work performed

1. Introduction

Earned Value Management (EVM) is an integrated system of project management and control which enables a contractor and their customers to monitor the progress of a project in terms of integrated cost, schedule and technical performance measures. The EVM system is created, owned and managed by the prime contractor. Traditional project management practice tends to compare actual cost with planned (budget) expenditure. The comparison of budget versus actual cost merely indicates what was planned to be spent versus what was actually spent at any given time. With this approach there is no way to determine the physical amount of work performed. EVM provides a third reference point (the earned value of the physical work completed) which is an objective view of the status of the project, i.e. value to the end goal of the work completed to date. This can be compared with both planned and actual cost to determine the performance to date and to give early indications of problems. The difference between the earned value and the planned cost indicate "schedule" status (schedule variance) of the project. The difference between the earned value and the actual cost indicate "cost" status (cost variance) of the project. By using an EVM we can answer the following questions at any given time: 1-st. Where have we been?, 2-nd. Where are we now? and 3-rd. Where are we going?

2. The EVM framework

The EVM framework can be divided into three phases:

1. Input – what is need to implement Earned Value
2. Earned Value Methods – formulas, metrics and performance measurements used
3. Output – reporting requirements

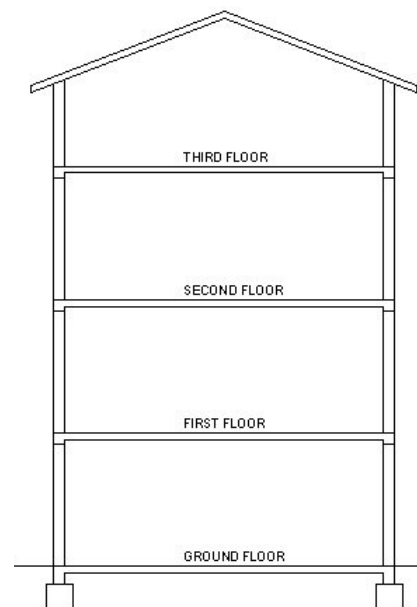
The inputs required for an EVM include Work Breakdown Structure (WBS), Organizational Breakdown Structure (OBS), Project Schedule, Cost/Resource and Time-phased Baseline Budget. The second phase is the Earned Value Methods which include Planned Cost, Earned Value, Actual Cost, Metrics and Performance Measurement and Forecasting. The last phase of Earned Value is the outputs which include Reporting requirements, Proper Analysis and Correct Action taken. The following parts describe the three phases.

3. The Input

The heart of EVM is the Work Breakdown Structure (WBS). Planning a construction project using EVM is no different than the initial planning necessary to implement any given construction project. There are three basic items in the process of planning any project: Scope, Schedule and Cost. A tool to help capture and control a project scope is the WBS. The WBS defines a project discrete work elements in a way that helps organize and define the total work scope of the project. A WBS element may be a product, data, a service or any combination. Each descending level of the WBS represents an increased level of detailed definition of the project work. In developing a WBS there are multiple ways to develop it for any given project. The most important items that must be considered when developing the WBS are approved scope, the way to manage the project, size of the project, reporting requirements, resources executing the work and complexity of the project. Below is an example of the WBS in the Tree format (4 level) for the construction project of a single building with 3 floor (picture 1).

Contractor – Level 1

1. Building construction – Level 2
 - 1.1. Earthworks – Level 3
 - 1.1.1. Scoop – Level 4
 - 1.1.2. Filling – Level 4
 - 1.2. Concrete – Level 3
 - 1.2.1. Foundation – Level 4
 - 1.2.2. Ceiling (1-st floor) – Level 4
 - 1.2.3. Ceiling (2-nd floor) – Level 4
 - 1.2.4. Ceiling (3-rd floor) – Level 4
 - 1.3. Walls – Level 3
 - 1.3.1. Ground floor – Level 4
 - 1.3.2. First floor – Level 4
 - 1.3.3. Second floor – Level 4
 - 1.3.4. Third floor – Level 4
 - 1.4. Roofing – Level 3
 - 1.4.1. Roof construction – Level 4
 - 1.4.2. Covering – Level 4



Picture 1.: The section of a single building

The lower elements (activities/tasks) of the WBS should be planned to the greatest possible detail, and they enable us to manage the project. EV is based on assigning a value at the activity level to the achievement of project work. Once the WBS is complete, the appropriate resources and responsibilities need to be assigned. The first step is developing the Organizational Breakdown Structure (OBS) for the project that indicates the organizational relationships and which is used as the framework for assigning work responsibilities. The second step is to merge WBS and OBS and to create a Responsibility Assignment Matrix (RAM) that displays the lowest level of both the WBS and OBS. The integration identifies specific responsibility for specific project activities. Below is an example of the RAM with the quantities for each activity works for the construction project of a single building (picture 2.).

Performing	1. - Building Construction											
Dept.	1.1.		1.2.				1.3.				1.4.	
	1.1.1.	1.1.2.	1.2.1.	1.2.2.	1.2.3.	1.2.4.	1.3.1.	1.3.2.	1.3.3.	1.3.4.	1.4.1.	1.4.2.
Earthwork.	300	200										
Conc.			100	60	60	60						
Walls							50	50	50	35		
Roof.											70	400

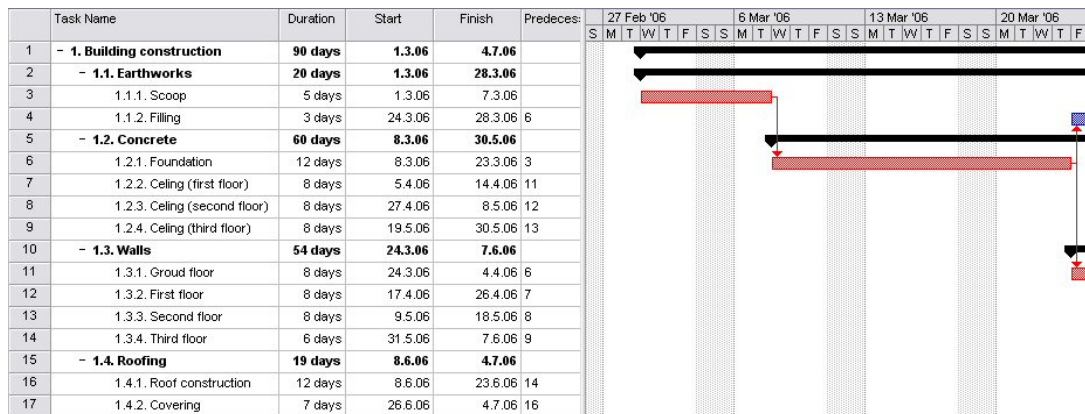
Picture 2.: The Responsibility Assignment Matrix (RAM) of a single building

The next step in this process is to develop the project schedule that is development of planned dates for performing project activities and meeting milestones. Scheduling includes the project start and completion dates, project deliverables and milestone dates, and the start and completion dates for all activities needs to successfully complete the project. Project scheduling in the EVM involves five step process:

1. Develop the list of project activities
2. Sequence the list of project activities
3. Determine the relationships between activities
4. Establish the duration for each activity
5. Determine the project duration (start and completion dates)

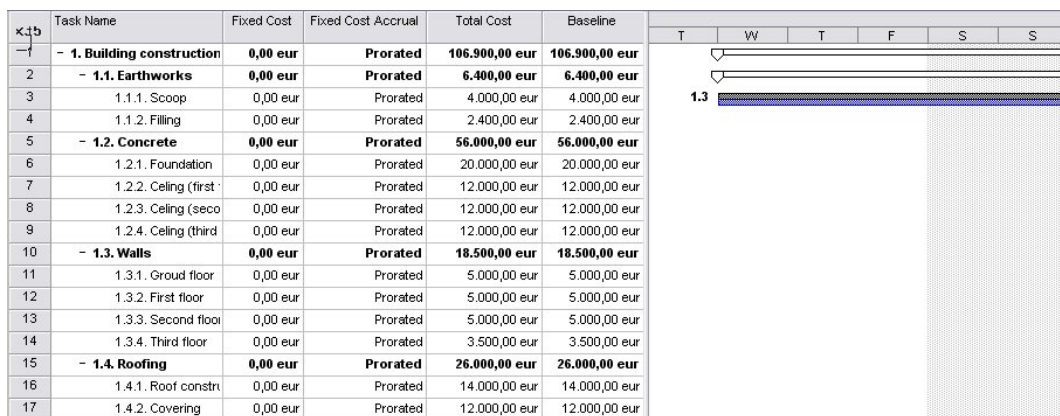
Once the activity list and sequence of project activities have been established its necessary to determine the direct relationships between each activity. Identifying direct relationships between activities (a Network Diagram) in scheduling provides greater understanding of the project tasks, i.e. to identify the sequence plus dependencies of the tasks. It will be used Precedence Diagramming Method (PDM) for developing project sequence and relationships. After the project network diagram has been finished its necessary to establish the duration of each project activity. Establishing the duration of each project activity involves determining the work period needed to complete each activity. The final step in this process is to determine the project duration, and the start and finish dates for each individual activity. In this example Critical Path Method (CPM) is used with the most likely time estimate for each activity. The project duration and activity start and completion dates will be determined in a scheduling software application, i.e. MS Project in this example. The software calculation gives the total project duration and the start and finish dates for each activity. Additionally, the process determines the critical path which tells us the activities that cannot slip without increasing the total duration of the project and float activities which can slip without impacting the total project duration. Once the project has started, logic sequence, relationships, and project duration has been approved, the schedule is then "baselined" to measure schedule performance. In displaying the schedule baseline, there are multiple ways that have been used, i.e. Gantt or Bar Chart or Network Diagram. Below

is presented a Gantt chart (picture 3.) as the result of the project schedule process for the construction project of a single building.



Picture 3.: The Gantt chart of a single building

One of the key criteria for establishing an EVM is that all major components (scope, schedule, cost) of a project must be integrated and baselined. Baseline, known as the Performance Measurement Baseline (PMB), is the original approved plan that consists of both schedule and cost, and which is used as the foundation for measuring project performance. The cost and schedule performance are measured against a baseline to help track the progress of the project. Based on the Project Scope and available resources, the project budget is allocated across the scheduled activities and across time. The time phased allocation of resources establishes the cost Baseline. The WBS is the framework used for cost calculation and budgeting. A Control Account (CA) is an assigned WBS level used to monitor the cost and schedule performance of each element of work. Each CA has a Control Account Manager appointed for cost summarization, variance analysis, reporting and corrective actions planning. At the lower elements (activities/tasks) of the WBS will be detailed budgets developed, stated, and then summarized at the CA level for reporting. The budgets are assigning to WBS elements in the process of cost calculation of construction works projects. The resources (labour, materials and subcontracts) required to complete each defined element of work are developed in terms of money. This process of assigning resources to each task, based on the Labour Hours, Material and other direct costs plus all the indirect rates define the price for each WBS element. Below is presented the Cost Baseline (picture 4.) as the result of the process of costs calculation for the construction project of a single building.



Picture 4.: The Cost Baseline of a single building

4. Earned Value Methods

In order for EVM to be implemented the Contractor must have a validated system that can accurately measure the following three fundamental factors:

1. The planned costs, known as the Budgeted Cost of Work Scheduled (BCWS)
2. The actual cost, known as the Actual Cost of Work Performed (ACWP)
3. The earned value, known as Budgeted Cost of Work Performed (BCWP).

Cost and Schedule baseline refers to the physical work and approved budget to accomplish the scheduled work, and they result as Planned Cost, or BCWS. Actual Cost (AC) is the cost for executing work on a project. Earned Value is determined by what has been physically accomplished by measuring the progress of a given activity of the project to the date. There are numerous EV methods to measure progress, i.e. fixed formula or units complete. Earned value performance measurements look at the project cost and schedule performance by analysing the cost and schedule variance along with cost and schedule efficiency. The derived data elements are:

1. Variance Analyses:
 - Cost Variance (CV) = Earned Value (EV) – Actual Cost (ACWP)
 - Schedule Variance (SV) = Earned Value (EV) – Budget Cost (BCWS)
2. Performance Indices:
 - Cost Performance Index (CPI) = EV / ACWP
 - Schedule Performance Index (SPI) = EV / BCWS

If the result of the CV is negative, it means that for completing the work more money was spent than was planned, or the project has "overrun" budget. If the result of the SV is negative, it means that the project is behind schedule, or less work performed than scheduled. The CPI is a measure of Cost Efficiency, and if the result is less than 1.0, cost is greater than earned value. The SPI is a measure of Schedule Efficiency, and if the result is less than 1.0, project is behind schedule. The chart (picture 5.) below lists the project status results (cost performance measurement) to the date 1.4.2006.

Task Name	BCWS	EV	ACWP	SV	SPI	CV	CPI
1.1.1. Scoop	4000,00	4000,00	4500,00	0,00	1,00	-500,00	0,89
1.1.2. Filling	2400,00	2400,00	2800,00	0,00	1,00	-400,00	0,86
1.2.1. Foundation	20000,00	20000,00	20600,00	0,00	1,00	-600,00	0,97
1.3.1. Groud floor	3750,00	3125,00	3000,00	-625,00	0,83	125,00	1,04
Project Total	30150,00	29525,00	30900,00	-625,00	0,98	-1375,00	0,96

Picture 5.: The Project status to the date 1.4.2006. of a single building

What does this information tell us? A CV and SV tell us that the project is overrun budget and behind schedule. A CPI of 0,96 tell us that we are getting 0,96 worth of work for every 1,00 spent in terms of money. There are many potential causes of unfavourable CPI, i.e. work more complex than anticipated, market fluctuations in the cost labour or material etc. A SPI of 0,98 tells us that we are 2% behind schedule, or we are working at an 98% efficiency. There are many potential causes of unfavourable SPI, i.e. work more complex than anticipated, manpower shortage, supporting organizations behind schedule, late vendor delivery etc. In review of the activities, Ground floor is the activity causing the project to be behind (SPI=0,83) schedule, and at the cost side the Scoop, the Filling and the Foundation are the activities which cause overrun budget of the project. Using the project parameters to the date its necessary to complete this analysis and anticipate future progress that requires determining when the project will be completed and how much it will cost to complete it. The Estimate at

Completion (EAC) is the actual cost to date plus an objective estimate of costs for remaining work or estimate the total cost at the completion of the project. The Budget at Completion (BAC) is the sum of all budgets allocated to a project scope. There are multiple ways to develop an EAC. The EAC formula should be determined by the specifics of the project. EAC is used to determine the Variance at Completion (VAC) for the project. The VAC is calculated as following: $VAC = BAC - EAC$. If the result is negative, project is facing an overrun. Below the method of calculating the EAC for the construction project of a single building is presented.

$$EAC = BAC / CPI = 106900,00 / 0,96 = 111354,20$$

$$VAC = 106900,00 - 111354,20 = - 4454,20$$

Forecasting the final cost of the project using this EAC calculation the total cost is projected to overrun by 4454,20 eur. Also, one of the advantages of EVM is the ability to use the data to predict the final end date. This can be calculated as follows:

$$\text{Final project duration} = \text{Planned project duration} / SPI = 90 / 0,98 = 92 \text{ days}$$

Therefore we should take corrective actions if the project will be completed under budget and schedule.

5. The Output

The last phase of Earned Value is the Reporting. There are several reports which may be used for EVM Reporting and Analysis. These reports generally are for the costumer contractor discussions. The most commonly used reports are Cost Performance Report (CPR) and Cost/Schedule Status Report (C/SSR). The CPR is normally a monthly report and has five different formats which are applied to a contractor requiring EVM. They are Work Breakdown Structure (WBS), Organizational Breakdown Structure (OBS), Baseline, Staffing and Variance Analysis Report. All Performance Measurement data reported in the CPR are derived from the formal EVM. The C/SSR is used primarily for reporting cost and schedule summary data which include cumulative and at complete summaries of each WBS element, than data about contract price, budget, Management Reserve etc. The Reports refer to making decisions and taking corrective actions.

6. Conclusion

The simple analysis described in the paper illustrates the application of a tool for project managers used to objectively evaluate cost and schedule efficiency of construction projects. EVM provides cost, schedule and technical performance data which is at the centre of good decision making. The benefits to project management come from the disciplined approach to planning, an ability to performance metrics and to accurately forecast future performance. EVM is applicable to all types of project and all phases of the project cycle. Some of benefits using EVM are objective information of the project status, the ability to identify where it is going right and where it is going wrong, an ability to predict with reasonable accuracy the future direction of the project. One of the key criteria for implementing an EVM is that scope, schedule and cost of a project are integrated and baselined. Once the performance measurement baseline has been established, then cost and schedule performance metrics follows to help track the progress of the project. Using the project parameters to the date it is possible to determine when the project will be completed and how much it will cost. If the project cost and schedule are over budget and behind schedule it is necessary to take corrective actions if the project is to be completed under budget and schedule.

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