TOWARDS EFFECTIVE EARNED VALUE TECHNIQUE IN CONSTRUCTION MANAGEMENT

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ABSTRACT

In traditional project management, experts used to monitor each of cost and schedule apart from each other; however, this is not the clever way to do that. Earned Value is considered the best technique to correlate, analyze and compare the project’s scope, schedule and cost to evaluate current project performance and estimate future values required for planning of corrective action, if needed.

This paper aims to illustrate the basic information required for creating Earned Value Management System through applying of simple example in addition to reviewing its main advantages and disadvantages. Also, this paper will present the evolution of the earned value technique in modern project management field such as the new reporting approach and earned schedule technique.


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1. INTRODUCTION

The main important factors for any project manager are Scope, Cost and Schedule. It is always a difficult question to be asked by the organization top management to the project manager, are you going to finish this project on time? Or would you need extra fund later? Project manager should be prepared to answer these questions in scientific way based on factual project measurements to convince the top management. The best way to answer these questions is the usage of Earned Value technique. If so, how did experts monitor project performance before they knew the earned value techniques?
In traditional project monitoring method, project managers used to monitor each of cost and schedule apart from each other; however, this is not the clever way to do that. There are two data sources: budget and actual expenditures. The comparison of budget versus actual expenditures indicates planned spending versus what was actually spent at any given time. This analysis does not address how much has been produced for the amount of money spent or if the investment is maturing according to schedule. In the other hand, Gantt charts lack the spend component. Pretty soon most projects get ahead or behind in spend and time and so trying to gauge the overall project health becomes difficult.

Figures 1 & 2 shows methods of project monitoring using traditional project management before the establishment of earned value techniques, where cost and schedule are evaluated separately.

![Figure 1: Cost Monitoring in Traditional Methods](image1)

![Figure 2: Schedule Monitoring in Traditional Methods](image2)

Each figure presents the project performance in one dimension only, cost or schedule wise. In order to combine both dimensions, earned value technique should be used. Earned value (EV) is a project management technique that has been used everywhere, to monitor and control costs and schedules of projects. It was created by the United States Defense Department in the 1960s to connect cost, schedule, and the “physical progress” achieved by the project team [1].

The main objective of (EV) technique is to calculate quantitative project performance indicators and predict future performance, which allow project team to manage their projects and proactively take corrective actions.
2. Earned Value Terminology

Earned value was defined in the Project Management Body of Knowledge [2], as follows: “Earned value (EV) is the value of work performed expressed in terms of the approved budget assigned to that work for an activity or work breakdown structure component”.

Using of Earned Value technique requires the awareness of few project measurements, which are presented in the following table [3].

<table>
<thead>
<tr>
<th>Term</th>
<th>Full Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>Planned Value</td>
<td>Estimated value of the work planned to be done</td>
</tr>
<tr>
<td>EV</td>
<td>Earned Value</td>
<td>Estimated value of the work actually accomplished</td>
</tr>
<tr>
<td>AC</td>
<td>Actual Costs</td>
<td>Actual Costs Incurred</td>
</tr>
<tr>
<td>BAC</td>
<td>Budget at Completion</td>
<td>Amount budgeted for total project</td>
</tr>
<tr>
<td>EAC</td>
<td>Estimate at Completion</td>
<td>Currently expected total cost of project</td>
</tr>
<tr>
<td>ETC</td>
<td>Estimate to Complete</td>
<td>How much more cost the project need to finish</td>
</tr>
<tr>
<td>VAC</td>
<td>Variance at Completion</td>
<td>How much over/under budget the project expects</td>
</tr>
</tbody>
</table>

These measurements are used to calculate the project performance indicators, which are presented in the following table.

<table>
<thead>
<tr>
<th>Name</th>
<th>Formulae</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Variance</td>
<td>CV=EV-AC</td>
<td>Negative: Over budget, Positive: Under budget</td>
</tr>
<tr>
<td>Schedule Variance</td>
<td>SV=EV-PV</td>
<td>Negative: Behind schedule, Positive: Ahead schedule</td>
</tr>
<tr>
<td>Cost Performance Index</td>
<td>CPI=EV/AC</td>
<td>Project is getting cents out of every $ spent</td>
</tr>
<tr>
<td>Schedule Performance Index</td>
<td>SPI=EV/PV</td>
<td>Project is progressing at ……% of the rate originally planned</td>
</tr>
<tr>
<td>Estimate at Completion</td>
<td>EAC=BAC/CPI</td>
<td>As of now, how much the total project is expected to cost,</td>
</tr>
<tr>
<td>Estimate to Complete</td>
<td>ETC=EAC-AC</td>
<td>How much more to finish</td>
</tr>
<tr>
<td>Variance at Completion</td>
<td>VAC=BAC-EAC</td>
<td>How much over/under the project is expected to be</td>
</tr>
</tbody>
</table>

The above mentioned project performance indicators are used to evaluate the current project performance and predict the future performance regarding schedule and cost.

It must be noticed that value of “Estimate at Completion” may be calculated in four different ways, according to project circumstances [4]:

a) EAC = BAC/CPI

Used when No variances from the BAC have occurred

b) EAC = AC+ ETC

Used when original estimate was fundamentally flawed or conditions have changed and invalidated original estimating assumptions

c) EAC = AC + BAC - EV

Used when past variances are not normal and things will be normal going forward from here.
d) EAC = AC + ((BAC - EV) / (CPI x SPI))

Used when current variances are thought to be typical in the future

Finally, everyone should pay high attention to choose the appropriate formula to calculated EAC. Incorrect calculation of EAC will lead to wrong decision taken by project management team, which will negatively impact project cost or schedule.

The relationship between basic earned value component and the project performance indicators is presented in the following figure [5].

![Figure 3: Project Performance Indicators](image)

### 3. PRACTICING EARNED VALUE CALCULATION

The following example explains the terms and formulas used during the calculation of earned value technique.

Imagine a project with total estimated budget (BAC) 100 million USD. According to our original plan, the baseline indicated that value of work, which should be completed as planned till now (PV) is 50 million USD, while our records show that project have completed (EV) USD 40 million of work, while actual expenditure (AC) is USD 35 million.

Therefore, the components of earned value may be presented in the following table, according to the terms stated in table 1.

<table>
<thead>
<tr>
<th>Term</th>
<th>Full Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>Planned Value</td>
<td>USD 50 million</td>
</tr>
<tr>
<td>EV</td>
<td>Earned Value</td>
<td>USD 40 million</td>
</tr>
<tr>
<td>AC</td>
<td>Actual Costs</td>
<td>USD 35 million</td>
</tr>
<tr>
<td>BAC</td>
<td>Budget at Completion</td>
<td>USD 100 million</td>
</tr>
</tbody>
</table>

Thus, the results of project performance indicators are calculated using the formulas in table 2 and the earned value components in table 3.
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<p>| Table 4: Value of Project Performance Indicators |</p>
<table>
<thead>
<tr>
<th>Name</th>
<th>Formulae</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Variance</td>
<td>CV = EV - AC</td>
<td>Positive: Project is costing less than the estimated budget.</td>
</tr>
<tr>
<td></td>
<td>40 – 35 = 5</td>
<td></td>
</tr>
<tr>
<td>Schedule Variance</td>
<td>SV = EV - PV</td>
<td>Negative: Project is behind the planned schedule.</td>
</tr>
<tr>
<td></td>
<td>40 – 50 = -10</td>
<td></td>
</tr>
<tr>
<td>Cost Performance</td>
<td>CPI = EV/AC</td>
<td>Project is getting 14 cents out of every $ spent.</td>
</tr>
<tr>
<td>Index</td>
<td>40/35 = 114%</td>
<td></td>
</tr>
<tr>
<td>Schedule Performance Index</td>
<td>SPI = EV/PV</td>
<td>Project is progressing at 80% of the rate originally planned.</td>
</tr>
<tr>
<td></td>
<td>40/50 = 80%</td>
<td></td>
</tr>
<tr>
<td>Estimate at Completion</td>
<td>EAC = BAC / CPI</td>
<td>As of now, the total project is expected to cost USD 87.5 million.</td>
</tr>
<tr>
<td></td>
<td>100/1.14 = 87.5</td>
<td></td>
</tr>
<tr>
<td>Estimate to Complete</td>
<td>ETC = EAC - AC</td>
<td>Project needs USD 52.5 million to be completed.</td>
</tr>
<tr>
<td></td>
<td>87.5 - 35 = 52.5</td>
<td></td>
</tr>
<tr>
<td>Variance at Completion</td>
<td>VAC = BAC - EAC</td>
<td>Project is USD 12.5 million under the estimated budget.</td>
</tr>
<tr>
<td></td>
<td>100 – 87.5 = 12.5</td>
<td></td>
</tr>
</tbody>
</table>

It is obvious by taking one glance to the project performance indicators that this project is progressing under budget and behind schedule. This requires the implementation of corrective action regarding the schedule delay, which may include crashing or fast tracking. Moreover, the project performance indicators also show that part of the 5 million USD (positive deference between PV & AC) may be used in crashing activities.

4. ASSSESSMENT OF PROJECT PERFORMANCE INDICATORS

A simple presentation of project performance indicators may be obtained just by presenting both cost and schedule performance index (CPI & SPI), to obtain a comprehensive figure over the project performance [6].

![Figure 4: Presenting both Cost and Schedule Performance Index](image)

Another graphical method for assessment of project situation using the project performance indicators in earned value technique [7].
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**Figure 5**: Assessment of Project Performance Indicators

5. **FORECAST OF ESTIMATED PROJECT COST**

Using Earned Value management system to control construction project cost and predicting the expected cost is very important to all project stakeholders [17].

Four formulas may be used to estimate total project cost, Estimate at Completion (EAC), based on project circumstance:

1. \[ EAC = \frac{BAC}{CPI} \]
   
   If the CPI is expected to be the same for the remainder of the project

2. \[ EAC = BAC + AC - EV \]
   
   Past variances are not typical and future work will be accomplished at the planned rate.

3. \[ EAC = AC + \left( \frac{(BAC - EV)}{(CPI \times SPI)} \right) \]
   
   If both the CPI and SPI influence the remaining work

4. \[ EAC = AC + \text{Estimate to Complete (ETC)} \]
   
   If the initial plan is no longer valid.

Project stakeholders should pay careful attention to which formula to be used according to the current and expected project circumstances. It should be noticed that using of the wrong formula will affect the accuracy of cost estimate at the project completion [18].

5. **EARNED VALUE ADVANTAGES**

Several advantages of earned value analysis could be mentioned.

5.1 **Simple**: Earned value technique depends on few measurements, which does not need long experience to understand its basic components. Also, earned value calculation is not complicated and may be performed at site without the need for computer or fancy software.

5.2 **Quick**: once you calculate your project performance indicator using earned value technique, it will tell you instantly the cost and schedule situation.

5.3 **Representative**: it may take hours to explain the details of your project performance regarding cost and schedule, while you can only present the values of your project
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performance indicators within few minutes. Results of several researches revealed that Earned Value analysis was a breakthrough in detecting problems, constraints and factors which have an impact on the construction projects [16].

5.4 Visual: The reporting capabilities of earned value technique are very wide and extending every day. Presentation of earned value results in graph is better as it engages the right-side of the brain, which draws more mental power to understand, interpret and plan appropriate responses. Visual graphs are also better to discuss and collaborate on since everyone can point, annotate and extrapolate easier than with words or numbers.

5.5 Leading: The best feature in the earned value technique is it considered a leading Indicator as it tries to predict completion dates and final costs. This allows us to re-plan and change our approach.

6. EARNED VALUE CRITIQUES

Project stakeholders now could say fine, let us use the earned value it is perfect, however this is not completely true as there are other significant issues.

6.1 Quality: The values obtained from earned value technique are not enough alone to evaluate the project performance as a whole. Project could be on time and on budget, but building a horrible product that the business does not like or is low in quality. Experts should be aware that cost and schedule are just a part of the picture, not the whole picture.

6.2 Health & Safety: When earned value concentrated over time and cost, other factors were disregarded, such as customer satisfaction, health and safety.

6.3 Calculations: Although that earned value is considered simple, but choosing inappropriate formulas to calculate “Estimate to complete” may lead to incorrect values and decisions.

6.4 Limitation: Earned Value requires quantification of a project plan; therefore, it is not always applicable to research or development projects.

6.5 Discrete: Traditional earned value technique was based on the discrete values in project plan and is not intended for continuous effort, which creates difficulties to its usage in many fields.

6.6 Risk: Earned value forecast of total project cost at completion could be misleading, as it could be affected by project risk, which is not considered in earned value analysis.

7. EVOLUTION OF EARNED VALUE TECHNIQUE

During the last few years, earned value technique has gained popularity all over the world in deferent project management fields. Therefore, it was developed to suit user needs and expectations. This section will explore the new improvement initiatives in the field of earned value technique.

7.1 Additional Performance Measures: In traditional earned value technique, the common practice usually calculate cost and schedule variances encountered in projects in terms of money (dollars). The modern practice presented additional performance measure such as man-hours, milestones or even given points [8].

7.2 Report Enhancement: As discussed before in this paper, the reporting capabilities of earned value technique are simple and representative. Moreover, the new research enhanced these capabilities. As illustrated in the following graph, a familiar spend line tracking to the dollar scale on the right hand axis; and also a feature based line shown in blue tracking against the points scale on the left. The line slope indicates project progressing. Where it rises steeply it indicates a lot of points developed in a short time, where it is flat, progress was slow [9].
7.3 **Earned Schedule:** Traditional earned value measures have main focus on cost, as it relates the accomplished work value to the planned value of the same date. In earned schedule (ES) performance measures is measured in units of time, rather than cost. Using of earned schedule technique allows for better accuracy of predicting potential schedule variance in future and takes the required preventive actions [1].

7.4 **Earned Value Software:** Many software packages were developed to manage earned value technique; the software packages range from simple package with few options available in low price to the fancy package with huge capabilities affordable by giant companies only [19].

**8. CREATING EARNED VALUE MANAGEMENT SYSTEM**

As a result of all previous discussion, the following steps were recommended by the researcher for creating an effective earned value management system. Noncompliance with these steps may produce inaccurate project performance indicators, which will lead to poor management decisions:

**8.1. Define Work Scope**

Use available information from project stakeholders and inquire for missing or ambiguous data to define work scope in project precisely. Any missing work scope will not be considered in baseline will not be considered during earned value calculation and will negatively impact your project performance indicators. The following figure presents the work scope decomposition into work packages in the usual Work Breakdown Structure (WBS).
8.2. Determine Schedule
Identify work package duration and explore the possible relations to determine the appropriate project schedule, taking into consideration the availability of the resources required for execution. The following figure presents sequence of work package in simple bar chart.

Figure 8: Bar Chart Schedule

8.3. Allocate Budget
Determine cost of every work package and add it over the previously established schedule. Next figure shows the addition of cost to each work package to project schedule in the bar chart.

Figure 9: Cost added to Bar Chart

8.4. Create Baseline
Merging project schedule with work packages’ cost will generate the project baseline presented in the next figure.

Figure 10: Project Baseline

8.5. Monitor Current Project Performance
Measure and calculate components of earned value periodically: Earned Value, Actual Cost, Schedule Variance, Cost Variance, Schedule Performance Index and Cost Performance Index.
8.6. Evaluate Current Project Performance
Calculate project performance indicators and compare it with planned value to spot any deviation.

8.7. Recommend Corrective Action
Use your knowledge and skills and consult with project stakeholder to identify root cause of any negative variation and address the appropriate recommendations to overcome poor performance.

8.8. Forecast Future Project Performance
Calculate the expected project performance indicators to predict any potential deviation to planned value in future.

9. CONCLUSION
Earned value technique is recommended for project monitoring and management, as it correlates project’s scope, cost and schedule all together. Among the several benefits of using earned value technique is the simple and quick calculations, which does not require professional to perform it. Other benefit is the excellent capabilities of reporting. However, the most significant advantage of earned value technique to any other project management technique is its ability to predict future project performance, which allows us to investigate reasons and recommend for the appropriate action.

    Despite all the previous benefits of earned value technique, it is still evolving by exploring additional performance measures and enhancing the reporting. However, the major evolve in earned value technique was through the developing of its strength in accurate prediction of project completion date using the new approach of earned schedule.

    Finally, project stakeholders admit that earned value technique is great, but it should not be considered as a magic stick that will solve all our problems. It only tells where problems are and suggest corrective action. Experts should be aware that earned value does not include the quality dimension, which may lead to false performance indicators. Also, stakeholders should be careful in choosing the appropriate formula to calculate the Estimate at Completion, by taking all project circumstances in considerations. All previous disadvantage of earned value technique is considered minor with regard to the limitation of its usage to discreet value and non-research project, however the scientist is still working for developing solutions to these limitations till date.
REFERENCES


