Optimization on Earned Value Method Combined with Critical Path

Qi-bin Zheng and Xing Bi

Abstract When calculating the schedule performance using the traditional earned value method, the earned value in the critical path and in the noncritical path is not differentiated. It cannot evaluate the progress of project objectively. In this paper, the schedule performance indicators are optimized through introducing the weight value, and schedule performance on the critical path is analyzed. The critical path issues in the evaluation of the progress of the project are solved, which will provide a basic point of reference for schedule measurement of project.

Keywords Critical path • Earned value method • Optimization • Weight value

1 Introduction

1.1 Introduction to the Earned Value Method

Earned Value analysis is a method of performance measurement which integrates cost, schedule and scope and can be used to forecast future performance and project completion dates [1]. The earned-value measurement concept was first introduced to the American defense contracting community when the government issued the Department of Defense and NASA Guide to Cost. Its techniques can still be applied to the smaller projects currently in use today. Indeed, as Microsoft Project allows you to drill down through and across a project, specific variances and general trends can be easily found. Its biggest feature is the combination of the two indicators of

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Table 1 Earned value management terms

Term	Description	Interpretation
PV	Planned value	What is the estimated value of the work planned to be done?
EV	Earned value	What is the estimated value of the work actually accomplished?
AC	Actual cost	What is the actual cost incurred?

Table 2 Earned value management formula and interpretation

Term	Formula	Interpretation
CV	EV – AC	Negative is over budget
		Positive is under budget
SV	EV – PV	Negative is behind schedule
		Positive is ahead of schedule
CPI	EV/AC	Greater than 1.0 indicates work is accomplished for less cost than what was planned or budgeted
		Less than 1.0 indicates the project is facing cost overrun
SPI	EV/PV	Greater than 1.0 indicates work is accomplished for less time than what was planned or budgeted
		Less than 1.0 indicates the project is facing time overrun

cost performance and schedule performance, supported by the payment system of incentives, which can improve capital efficiency and labor productivity in the project effectively [2]. Traditional earned value management is a kind of three-dimensional index system that contains the project scope, schedule and cost and is created by the introduction of the earned value variable [3].

Three quantities form the basis for cost and schedule performance measurement using Earned Value Management. They are Planned Value (PV), Earned Value (EV) and Actual Cost (AC) (Table 1). Additional terms are defined to record cost and schedule performance and program budget:

Schedule Variance (SV) – The difference between the work actually performed (EV) and the work scheduled (PV). The schedule variance is calculated in terms of the difference in dollar value between the amount of work that should have been completed in a given time period and the work actually completed.

Cost Variance (CV) – The difference between the planned cost of work performed (EV) and actual cost incurred for the work (AC). This is the actual dollar value by which a project is either overrunning or under running its estimated cost.

Cost Performance Index (CPI) – The ratio of cost of work performed (EV) to actual cost (AC). CPI of 1.0 implies that the actual cost matches to the estimated cost.

Schedule Performance Index (SPI) – The ratio of work accomplished (EV) versus work planned (PV), for a specific time period. SPI indicates the rate at which the project is progressing (Table 2) [4–6].

1.2 Defects of EVM

Traditional earned value method treats the project as a whole, focusing on the macro- analysis of project performance. It cannot distinguish the critical path from noncritical path activities, ignoring the restraining effect of the critical work on the entire project. For example, the earned value is less than the planned value in some projects behind schedule. On the contrary, the earned value is more than the planned value in some projects ahead of schedule. As long as the cumulative earned value of the entire project is enough, it can achieve a prefect project performance compared with the planned value. While the actual progress of the project implementation has not been reflected accurately [7–9].

2 Methodology

2.1 Optimization of Schedule Performance Indicators

The weight value is introduced in order to distinguish critical work from noncritical work in the calculation of schedule performance indicators.

2.1.1 Selection of Weight Value

In project management, Total Float (TF) is the amount of time that a task in a project network can be delayed without causing a delay to project completion date. An activity on critical path has zero free float [10]. Total Float can distinguish critical work from noncritical work and reflect various impacts on the entire project duration. Therefore, select

$$k_i = e^{(-TF_i)} \Big/ \sum_{i=1}^{n} e^{(-TF_i)} \tag{1}$$

as the weight value for activity i in the k-th day. k_i meets the following conditions:

$$0 \leq k_i \leq 1 \tag{2}$$

$$\sum_{i=1}^{n} k_i = 1 \tag{3}$$

2.1.2 Schedule Performance Indicators Modified

Planned Value of activity i in the k-th day with weight

$$PV_{k_i} = PV_i \times k_i \tag{4}$$

Planned Value of all activities in the k-th day with weight

$$PV_k = \sum_i PV_{k_i} \tag{5}$$

Earned Value of activity i in the k-th day with weight

$$EV_{k_i} = EV_i \times k_i \tag{6}$$

Earned Value of all activities in the k-th day with weight

$$EV_k = \sum_i EV_{k_i} \tag{7}$$

Schedule Variance in the k-th day with weight value

$$SV_k = EV_k - PV_k \tag{8}$$

Schedule Performance Index in the k-th day with weight [11]

$$SPI_k = EV_k / PV_k \tag{9}$$

2.1.3 Steps of Earned Value Analysis with Weight

Step 1: TF_i of work i is calculated according to the network diagram. And identify key work on critical path.
Step 2: The weight value for activity is calculated.
Step 3: Calculate Planned Value of activity i in the k-th day with weight PV_{k_i}. Then Planned Value of all activities in the k-th day with weight PV_k is also obtained.
Step 4: Calculate Earned Value of activity i in the k-th day with weight EV_{k_i}. Then Earned Value of all activities in the k-th day with weight EV_k is also obtained.
Step 5: Calculate Schedule Variance in the k-th day with weight value SV_k and Schedule Performance Index in the k-th day with weight SPI_k according the figures above.
Step 6: Analysis and gives the results of the evaluation of the project.

2.1.4 Earned Value Analysis Based on CPM

Schedule performance indicators modified show the difference between the critical path and noncritical path. Schedule performance on critical path can be measured. The strategy used is to assume two parameters: PV_{cp} (Planned Value on critical path) and EV_{cp} (Earned Value on critical path).

Schedule Variance on critical path

$$SV_{cp} = EV_{cp} - PV_{cp} \tag{10}$$

Schedule Performance Index on critical path

$$SPI_{cp} = EV_{cp}/PV_{cp} \tag{11}$$

SV and SPI on the entire project can be compared with SV_{cp} and SPI_{cp} on the critical path, which will determine schedule status on the critical path. These conditions can be divided into four types [12, 13]:

1. $SV < 0, SV_{cp} < 0$
   The work on the entire project and the critical path are behind schedule. It is high time to take certain measures to accelerate the implementation of activities on critical path and make sure whether activities on noncritical path can been completed in a given time period. If the deviation is not enough to cause a delay to project completion date, it is not necessary to take measures. Otherwise, there is a need to speed up the construction on noncritical paths and get schedule.
2. $SV < 0, SV_{cp} > 0$
   On the whole, the progress of the project will be delayed. But the work on critical path is ahead of schedule. Add more resources on noncritical paths and expedite the construction. It is necessary to avoid noncritical path convert into critical path.
3. $SV > 0, SV_{cp} > 0$
   The work on the entire project and the critical path actually performed are more than the work scheduled. The project can be fulfilled ahead of schedule. But it cannot be achieved at the expense of cost. It will affect the completion of future work, if the cost is too high.
4. $SV > 0, SV_{cp} > 0$
   On the surface, the project is ahead of scheduled, while it is behind schedule in fact. Because the work on critical path is not completed in a given time period. The efficiency of the work packages on critical path should be improved and resources distribution should be optimized appropriately.

3 Application and Results

A project includes seven tasks: A, B, C, D, E, F, G. The network planning is showed in Fig. 1. The completion duration of the project planned is 22 weeks and project performance is monitored every week. EV, PV and SV of all work are measured in dollars. It is obvious that A-B-C-F-G is on the critical path. On the 7th week, all activities are assessed and the progress and costs related are shown in Table 1.

Performance Index figures in Table 3 can be calculated from Table 4.

We now have a clearer picture of the actual status of the work. In the following 7 weeks, task A, B, D have been fully completed. 25 % percentage of C and 60 % percentage of E have been accomplished. Task F and G have not started.

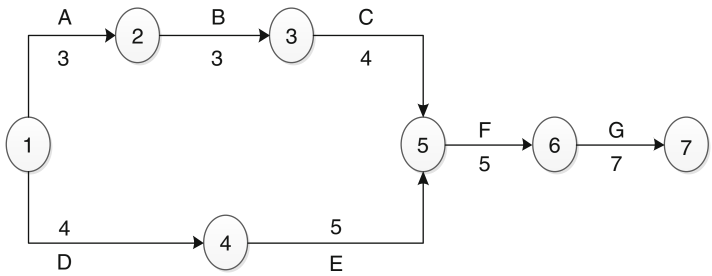

Fig. 1 The network planning of a project

Table 3 Summary of work schedule and performed

Task	PV	EV	Planed work/%	Actual work/%
A	90	110	100	100
B	100	100	100	100
C	70	0	25	0
D	100	120	100	100
E	80	140	60	100
F	120	0	0	0
G	150	0	0	0

Table 4 EV schedule analysis

Task	Duration	TF	Weight/%	PV_i	EVi	PV_{ki}	EV_{ki}
A	3	0	26.77	90	90	24.10	24.10
B	3	0	26.77	100	100	26.77	26.77
C	4	0	26.77	17.50	0	4.68	0
D	4	1	9.85	100	100	9.85	9.85
E	5	1	9.85	48	80	4.73	7.88

The results gained by earned value method are as follows:

$$PV = 355.5 \quad EV = 370$$

$$SV = EV - PV = 14.5$$

The whole project is ahead of schedule because $SV > 0$.

The figures gained by earned value method with weight value are as follows:

$$PV_k = 70.13 \quad EV_k = 68.6$$

$$SV_k = EV_k - PV_k = -15.3$$

The whole project is behind schedule because $SV_k < 0$.

Thus completely opposite results are drawn by different ways. In order to get the reasons, we continue do schedule performance analysis based on critical path. Some schedule performance indicators on critical path are calculated.

$$PV_{sp} = 207.5 \quad EV_{sp} = 190$$

$$SV_{sp} = EV_{sp} - PV_{sp} = -17.5$$

The work on critical path is behind schedule because $SV_{sp} < 0$.

It can be concluded that the project is ahead of scheduled on the surface, while it is behind schedule in fact. Because work E on the noncritical path actually performed is more than the work scheduled, while work C is on the contrary. The reason that E can be in advance is a significant increase in cost. Work D is completed timely which is also a reason for the added cost. So it is time to take certain measures to accelerate the implementation of activities on critical path. For example, we can increase the equipment and personnel inputs rapidly, take the advanced technical measures and dispatch resources appropriately, and so on. Meantime, the cost inputs on noncritical work packages should be controlled in case of increase in cost deviation [14–16].

4 Discussion

Schedule performance indicators including SV and SPI are measured by cost, not by time. This method is not intuitive, and it is also difficult to operate. Thus, it is necessary to do further research to optimize Schedule performance indicators.

5 Conclusion

Therefore, Earned Value Method is a better method of program management. It is an “early warning” program management tool that enables managers to identify and control problems before they become insurmountable. But we cannot gain accurate information about the project based on the overall analysis and evaluation of project by traditional earned value method. We can optimize schedule performance indicators by introducing weight value in order to distinguish critical work from noncritical work. Then we can do schedule performance analysis based on critical path. It can show project progress objectively and accurately and allow us take timely measures to correct deviations. It also provides a basic point of reference for schedule measurement of project and allows projects to be managed on time and on budget.

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