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Earned value management in project time control

Метод управления освоенным объёмом в контроле сроков проекта

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Ключевые слова: метод управления; освоенный объём; контроль сроков проекта; плановый объём; фактическая стоимость; метод управления освоенным объёмом

Abstract. The paper is devoted to earned value management, it describes the basic tools of this method, particular attention is directed to the indicators of the deviation of the time of the project. Also reasons for not using the method in practice are revealed. The main problem of the method of earned value management – the impossibility of its application to project time control, analyzed ways to solve this problem, proposed by W. Lipke, were identified. As an example, a project consisting of 8 works was reviewed. It has been reviewed three cases of possible cost sharing between critical and non-critical activities. It is revealed that the method proposed by Lipke, is not suitable for the project, where the cost of critical activities is low. The conclusions are about the possibility of using the method for the project time control.

Аннотация. Статья посвящена методу управления освоенным объёмом, в ней описаны основные инструменты данного метода, особое внимание направлено на показатели отклонения сроков проекта. Также выявлены причины отказа от использования метода на практике. Выявлена основная проблема метода управления освоенным объёмом – невозможность его применения для контроля сроков проекта, проанализированы пути решения этой проблемы, предложенные У. Липке. В качестве примера был рассмотрен проект, состоящий из 8 работ. Было проанализировано три случая возможного разделения затрат между критическими и некритическими работами. Выявлено, что метод, предложенный У. Липке, не подходит для проектов, где стоимость критических работ невелика. Выводы содержат информацию о возможности использования метода для контроля сроков проекта.

Introduction

Current practice of the implementation of construction projects requires giving attention to the timeliness of work completion and commissioning of the object [1–3]. There are a number of projects for which the prevention of disruption of timing is very important, such as the Olympic objects in Sochi was necessary to complete and put in commission before the Olympic Games, football stadiums needed to build before the World Cup in 2018, etc [1–5]. Commissioning of these objects into operation later approved date (deadline) not only leads to a drastic reduction in the efficiency of the project, but often defeats the purpose of the implementation of the projects and can lead to the collapse of the program, which includes the project [6–9].

Therefore, when working with important projects, it is necessary to pay attention not only to the preparation and optimization of the calendar plan of the building, but also the formation of an effective system of monitoring, control and management of the project [10–15].

Practice of construction projects shows that the time of the completion of some of them can not be failure and timeliness of their implementation is an important management problem. However, some of the building projects realized in the "background" and the time of their completion is not important for project participants or the main criterion for the success of the project is to minimize the costs to the

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detriment of the duration of the project [12–15]. But in this paper such projects are not considered. The main objects of study are the projects that have disruption of the schedule leads to serious catastrophic consequences.

However, joint control of the two most important parameters (time and cost) can be realized on the basis of the method of Earned Value Management. The basic principles of this method have been known and used in the industrialized countries in the late 1800s. In the early 1960s the US Air Force for the first time officially used the concept of Earned Value in the design and implementation of a unique project “Minute Man Missile”. Due to the success of the application of this method has been introduced in the practice of project management and was legislated in the USA as mandatory for the implementation of projects [16].

Currently, there is little need to use the method of Earned Value Management both Russian and foreign practice in project management [17]. These experts in the field of application of the method of Earned Value Management as a K. Flemming and D. Koppelman give, in their opinion, the reasons for non-use of the method [17]:

- Method of Earned Value Management is not always and not for all is clear and can be difficult at first acquaintance with him.
- Method of Earned Value Management originally was to be used only for large systems and projects, such in the USA only 1 % of the projects using this method, and, in general, these projects involve the major systems of government.
- Method of Earned Value Management describes the current state of the project in some detail (which is not always satisfactory), and the management does not want to know all the negative information [17].

Due to state of this method in Russia it conducted a survey among experts project management sphere. Respondents should have been to give reasons for not using the method. The leader of the responses was the reason associated with the complexity of the link accounting systems and calendar planning. Also, the following reasons have been put forward: a lack of information on the practical application of the method of Earned Value Management and the absence of good reasons to use this method in the control of the project [16, 17].

However, the main reason for not using the method of Earned Value Management in practice is the impossibility of direct application to time control of the project [18]. Customer, first of all, interested in the project to be completed on schedule, that is, key information is how many days the execution of works is behind schedule (or ahead of him), and by using this method it is possible to determine the backlog in duration only in monetary terms. Therefore it is required to develop practical methods and algorithms for the application of this method in the time control [18, 19].

Methods

The method of Earned Value Management controls two important parameters of the project. These parameters are time and cost. Forecast of final duration and cost of the project can be obtained on the identified trends [18].

The main indicators of the method of Earned Value Management are [18, 19]:

- AC – Actual Cost.
- PV – Planned Value.
- EV – Earned Value.

In Figure 1 you can see a graphic image of the method of Earned Value Management. The planned value graphically represents the S-curve. It is a curve of planned distribution of cost (value) within the schedule from the beginning to the end of the work (project) [18, 19]. AC curve shows the actual money spent of the execution of the work (project) from the beginning to the actual date. The third curve EV shows money that has to be spent if the actually performed value of work (the project) to pay according to the plan [18, 19].

The graph shows the deviation of the time, cost and duration. The deviation of the curve AC from PV has cost variance (CV), determined by the formula:

$$CV=EV-AC, \tag{1}$$

where CV – cost variance; EV – budgeted cost (earned value); AC – the actual cost.

If CV > 0, there is a budget saving, and if CV < 0 – cost overruns [20].

The deviation of the curve EV from PV has Schedule Variance (SV), but it is expressed in monetary units, that is, the difference between the cost of the executed and planned works, determined by the formula:

$$SV=EV-PV \tag{2}$$

where SV – schedule variance; EV – earned value; PV – planned value [20].

If SV > 0 – the works are ahead of plan, and if SV < 0 – the works are lagging behind [20].

These two deviations can be calculated using the formulas and seen graphically. But the deviation of the duration (TV – Time Variance) is determined only graphically (Fig. 1) [20, 21].

Also relative indicators are introduced. Cost Performance Index is calculated as the ratio of the cost of executed works (EV) to actual cost (AC) and Schedule Performance Index is calculated as the ratio of earned value to the value which had to be done according to the schedule. If the CPI > 1, there is a budget savings, and if the CPI < 1 – cost overruns. Similarly, if the SPI > 1 – the works are ahead of schedule, and if the SPI < 1 – the works are lagging behind [18–21].

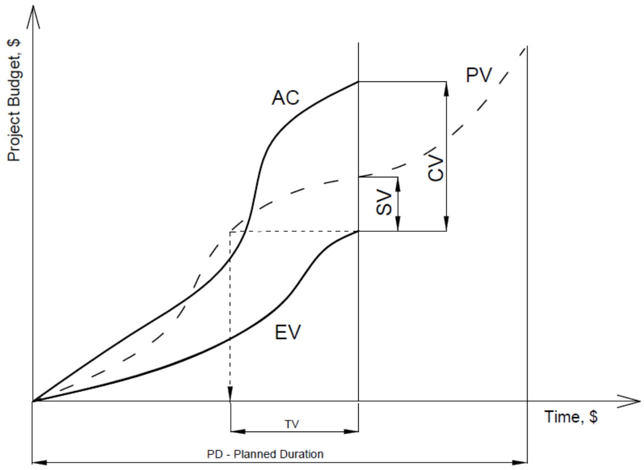

Figure 1. Graphical representation of Earned Value Management method

Also the Time Estimate at Completion (TEAC) may be determined based on the deviation in duration. Also the graph shows the planned parameters of the project: the planned budget of the project named Budget at Completion (BAC) and the planned duration of the project named Schedule at Completion (SAC) [19–22].

Results and Discussion

Compliance with deadlines is important in the implementation of construction projects. For some objects untimely completion of work could mean that the failure of the project. The method of Earned Value Management used for cost control can not be directly used to time control of the project. By this method to determine the backlog of the schedule can be graphically and in terms of money, but for the customer it is important to know that the backlog in days. The transition from the cost parameters to the time parameters is impossible because they have a fundamental difference: the final budget for the completion of the project consists of the cost of all work, and the project implementation time is determined by the critical path length, rather than the sum of the execution time of all the work [18–22]. Also, the time deviation indicators SV and SPI at the completion of the project with a delay do not indicate it [18–23].

This problem of the Earned Value Management method has been considered in the works of Walt Lipke, who developed the “Earned Schedule Concept”, using time parameters [18, 19]. The essence of this method is to find the time for which the EV will be equal to PV [18, 19]. The indicator ES is entered and named Earned Schedule. It can be determined graphically (Fig. 2) and algebraically by the formula (3):

$$ES=C+I, \tag{3}$$

where ES – time for which the EV will be equal to PV; C – the number of time periods for which the EV ≥ PV; I – an increment, which is determined by linear interpolation of the period C + 1 by the formula (4):

$$I=\frac{(EV-PV_c)}{(PV_{c+1}-PV_c)}, \qquad (4)$$

where I – the increment; EV – earned value; PV_c; PV_{c+1} – the planned values on the borders of the time period C + 1.

Then we can define indicators of the time deviation SV (t) and SPI (t), which will be determined by the formulas (5) and (6), respectively [18–21]:

$$SV(t)=ES-AT \qquad (5)$$

where SV (t) – the time deviation, months .; ES – time for which the EV will be equal to the PV, months; AT – actual time months.

$$SPI(t)=\frac{ES}{AT} \qquad (6)$$

where SPI (t) – the Schedule Performance Index; ES – time for which the EV will be equal to the PV, months; AT – actual time months.

If ES ahead ET, the SV (t) – is positive, and If ES is behind AT, the SV (t) – is negative. SPI (t) > 1, when ES exceeds AT, and SPI (t) < 1, when ES is smaller AT [18–21].

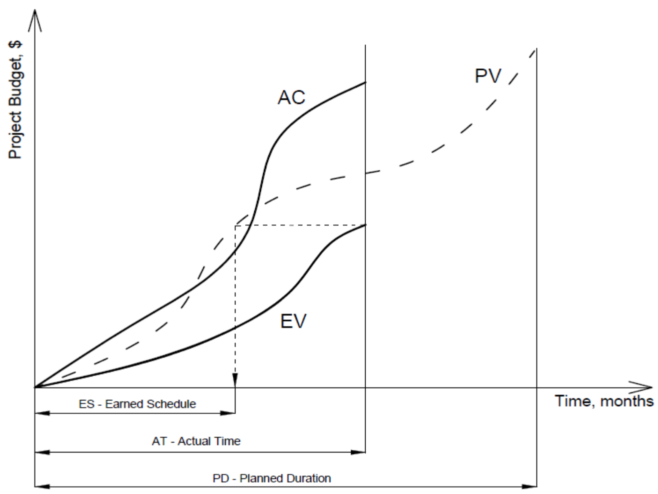

Figure 2. Graphical representation of the Earned Schedule Concept [23–25]

Let us try to test the theory of Walt Lipke by the example. Consider a project consisting of 8 works. (Fig. 3).

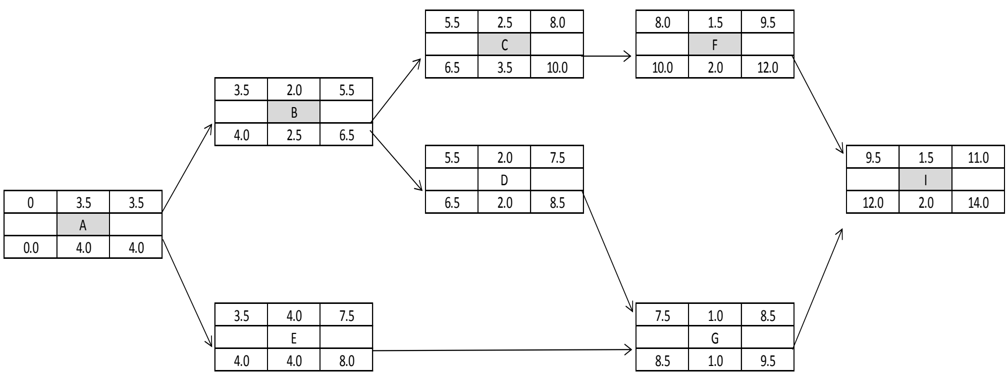

Figure 3. Project for an example

Parameters of the project work are shown in a Table 1. The project planned duration is 11 days, actual duration is 14 days, the critical path formed by the work A, B, C, F, I.

Table 1. Parameters of the project work

Work	Duration	Start	Completion
A	3.5	0	3.5
B	2	3.5	5.5
C	2.5	5.5	8
D	2	5.5	7.5
E	4	3.5	7.5
F	1.5	8	9.5
G	1	7.5	8.5
I	1.5	9.6	11

Consider three cases: 1 case where the critical activities constitute the main cost of the project (that is, critical activities are much more expensive than non-critical), 2 case where the value of the critical activities is a small part of the total cost (that is, the critical works are cheap compared to non-critical) and 3 case – the cost of critical and non-critical activities about the same [23–27].

In all three cases, the planned cost of the project is 1 million, all non-critical activities are done in a timely, but the timing of non-critical activities is failure. For each of the cases the actual date is 7 days. The main task is to calculate the time deviation SV (t), the Schedule Performance Index SPI (t) and forecast the timing of completion of project.

Case 1. The critical activities constitute the main cost of the project

Table 2. The distribution of PV by status dates for case 1

Work	Duration	PV	Days						
			1	2	3	4	5	6	7
A	3.5	100	28.57	57.14	85.71	100	100	100	100
B	2	300	0	0	0	75	225	300	300
C	2.5	250	0	0	0	0	0	50	150
D	2	30	0	0	0	0	0	7.5	22.5
E	4	40	0	0	0	5	15	25	35
F	1.5	150	0	0	0	0	0	0	0
G	1	30	0	0	0	0	0	0	0
I	1.5	100	0	0	0	0	0	0	0
Amount		1000	28.57	57.14	85.71	180	340	482.5	607.5

Table 3. The distribution of EV by status dates for case 1

Work	Duration	EV	Days						
			1	2	3	4	5	6	7
A	4	100	25	50	75	100	100	100	100
B	2.5	300	0	0	0	0	120	240	300
C	3.5	250	0	0	0	0	0	0	35.725
D	2	30	0	0	0	0	0	0	7,5
E	4	40	0	0	0	0	10	20	30
F	2	150	0	0	0	0	0	0	0
G	1	30	0	0	0	0	0	0	0
I	2	100	0	0	0	0	0	0	0
Amount		1000	25	50	75	100	230	360	473.225

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Table 4. The forecasting of the completion date project on the basis of EVM indicators for case 1

AT	C	I	ES	SV	SV(t)	SPI	SPI(t)	IEAC(t)
1	0	0.88	0.88	-3.57	-0.12	0.88	0.88	12.57
2	1	0.75	1.75	-7.14	-0.25	0.88	0.88	12.57
3	2	0.63	2.63	-10.71	-0.37	0.88	0.88	12.57
4	3	0.15	3.15	-80.00	-0.85	0.79	0.56	19.80
5	4	0.31	4.31	-110.00	-0.69	0.86	0.68	16.26
6	5	0.14	5.14	-122.50	-0.86	0.86	0.75	14.74
7	5	0.50	5.50	-134.28	-1.50	0.79	0.78	14.12

After analyzing the indicators, we see that the forecast is close to the actual duration. This means that the method of “Earned Schedule Concept” can be applied in this case.

Case 2. The cost of the critical activities is a small part of the total cost

Table 5. The distribution of PV by status dates for case 2

Work	Duration	PV	Days						
			1	2	3	4	5	6	7
A	3.5	15	4.2855	8.571	12.8565	15	15	15	15
B	2	0	0	0	0	0	0	0	0
C	2.5	0	0	0	0	0	0	0	0
D	2	350	0	0	0	0	0	87.5	262.5
E	4	300	0	0	0	37.5	112.5	187.5	262.5
F	1.5	5	0	0	0	0	0	0	0
G	1	320	0	0	0	0	0	0	0
I	1.5	10	0	0	0	0	0	0	0
Amount		1000	4.2855	8.571	12.8565	52.5	127.5	290	540

Table 6. The distribution of EV by status dates for case 2

Work	Duration	EV	Days						
			1	2	3	4	5	6	7
A	4	15	3.75	7.5	11.25	15	15	15	15
B	2.5	0	0	0	0	0	0	0	0
C	3.5	0	0	0	0	0	0	0	0
D	2	350	0	0	0	0	0	0	87.5
E	4	300	0	0	0	0	75	150	225
F	2	5	0	0	0	0	0	0	0
G	1	320	0	0	0	0	0	0	0
I	2	10	0	0	0	0	0	0	0
Amount		1000	3.75	7.5	11.25	15	90	165	327.5

Table 7. The forecasting of the completion date project on the basis of EVM indicators for case 2

AT	C	I	ES	SV	SV(t)	SPI	SPI(t)	IEAC(t)
1	0	0.88	0.88	-0.54	-0.12	0.88	0.88	12.57
2	1	0.75	1.75	-1.07	-0.25	0.88	0.88	12.57
3	2	0.63	2.63	-1.61	-0.37	0.88	0.88	12.57
4	3	0,05	3.05	-37.50	-0.95	0.76	0.29	38.50
5	4	0.50	4.50	-37.50	-0.50	0.90	0.71	15.58
6	5	0.23	5.23	-125.00	-0.77	0.87	0.57	19.33
7	6	0.15	6.15	-212.50	-0.85	0.88	0.61	18.14

As a result of the calculation obtained that the forecast exceeds the actual duration of 4 days that is a false result. This means that the method of “Earned Schedule Concept” can not be applied in this case [26, 27].

Case 3. The cost of critical and non-critical activities about the same

Table 8. The distribution of PV by status dates for case 3

Work	Duration	PV	Days						
			1	2	3	4	5	6	7
A	3.5	125	35.7125	71.425	107.1375	125	125	125	125
B	2	125	0	0	0	31.25	93.75	125	125
C	2.5	125	0	0	0	0	0	25	75
D	2	125	0	0	0	0	0	31.25	93.75
E	4	130	0	0	0	16.25	48.75	81.25	113.75
F	1.5	125	0	0	0	0	0	0	0
G	1	125	0	0	0	0	0	0	0
I	1.5	120	0	0	0	0	0	0	0
Amount		1000	35.7125	71.425	107.1375	172.5	267.5	387.5	532.5

Table 9. The distribution of EV by status dates for case 3

Work	Duration	EV	Days						
			1	2	3	4	5	6	7
A	4	125	31.25	62.5	93.75	125	125	125	125
B	2.5	125	0	0	0	0	50	100	125
C	3.5	125	0	0	0	0	0	0	17.8625
D	2	125	0	0	0	0	0	0	31.25
E	4	130	0	0	0	0	32.5	65	97.5
F	2	125	0	0	0	0	0	0	0
G	1	125	0	0	0	0	0	0	0
I	2	120	0	0	0	0	0	0	0
Amount		1000	31.25	62.5	93.75	125	207.5	290	396.6125

Table 10. The forecasting of the completion date project on the basis of EVM indicators for case 3

AT	C	I	ES	SV	SV(t)	SPI	SPI(t)	IEAC(t)
1	0	0.88	0.88	-4.46	-0.12	0.88	0.88	12.57
2	1	0.75	1.75	-8.93	-0.25	0.88	0.88	12.57
3	2	0.63	2.63	-13.39	-0.37	0.88	0.88	12.57
4	3	0.27	3.27	-47.50	-0.73	0.82	0.72	15.18
5	4	0.37	4.37	-60.00	-0.63	0.87	0.78	14.18
6	5	0.19	5.19	-97.50	-0.81	0.86	0.75	14.70
7	6	0.06	6.06	-135.89	-0.94	0.87	0.74	14.77

We see that the forecast is close to the actual duration. This is an acceptable result. This means that the method of “Earned Schedule Concept” can be applied in this case [26, 27].

Conclusions

Earned Value Management method used to control the cost of the project work, but it is equally important to control the time of the work execution. But for time control this method can not be applied directly. This is because the time control should be realized using time parameters, and Earned Value Management method uses cost parameters. This problem is trying to decide by applying the “Earned Schedule Concept” developed by Walt Lipke. But if critical works are inexpensive, this method can give a false result. As a conclusion, we can say that require the development of practical algorithms and methods of using this method to time control of the project.

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