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ON A CERTAIN EXTENSION OF THE EARNED VALUE METHOD

The Earned Value Method, a well know tool in project cost management, is enhanced by additional aspects, allowing to control not only the cost of the project, but also the cash flows, accounts payable, liabilities, stock level etc. The modification will make out of the Earned Value Method an even more efficient tool allowing to identify problems during the project realisation, before it is too late to solve them

1. Introduction

Project management is a very challenging task, as each project is unique and incorporates a lot of risk and uncertainty. What is more, it is always limited in time and once the due date has arrived, there is often no time any more to make up for the errors committed in the past. Some of those errors are due to uncertainty and cannot be eliminated, but some of them can, if we have a good warning system, which allows us, during the project realisation, to draw conclusions from what has happened in the past and to be able to do so on the basis of a few indicators, as usually nobody has time during the project realisation to carry out profound analyses. The Earned Value Method has the ambition to constitute such a warning system. If a company applies this method, for each project during its realisation, in selected control moments, certain indicators are calculated, which show some of the reasons of discrepancies between plans and reality and allow to draw conclusions (in a limited sense, of course, no miracles are possible here, what is uncertain or unknown, will not be made certain or known by any method) about the future of the project, before this future really happens - so that there is time to react if the future seems to be bringing a disaster.

In this paper we propose an extension of the Earned Value Method which will make out of it an even more efficient warning system. We propose to introduce into the method several additional indicators which will allow the project manager to see early enough as many phenomena as possible which might have a significant influence on the project future, e.g. referring to the behaviour of customers in their payments.

2. The classical Earned Value Method

The classical Earned Value Method. described e.g. in [1,2,3,4,5], can be used to control the project budget during the realisation of the project and to forecast, also during the realisation of the project, the final cost of the project and of its individual activities.

Let is denote the consecutive control points for a project by $t, t = 1,\ldots,n$, where t=1 corresponds to the beginning of the project and t=n to its end. Let us assume that the project is composed of m activities, denoted $a_i \ (i = 1,\ldots,m)$. The whole project will be denoted by P and will be treated as the set $\{a_i \ (i = 1,\ldots,m)\}$. Of course, in each moment $t = 1,\ldots,n$ the status of the individual activities may be of one of the following three types: not started, started and unfinished, finished.

The Earned Value Method calculates, for each t, the following values (X is a parameter denoting any subset of $\{a_i \ (i = 1,\ldots,m)\}$ – the whole project P, one activity or any other proper subset of P; if X denotes one activity a_i, we will write a_i instead of $\{a_i\}$:

- BAC(t,X) – Budget at completion: the whole budget of X according to the information at the moment t. BAC(1,X) is equal to the initially determined budget. In ideal conditions we would have BAC(t,X)= BAC(1,X) for each t, but in practice budgets are modified, e.g. as a result of a problem encountered during the project realization;
- BCWS(t,X) – Budgeted Cost of Work Scheduled: the cost – according to the initial budget BAC(1,X) - of the work that according to the initial schedule should have been realized in X till the moment t;
- BCWP(t,X) – Budgeted Cost of Work Performed: the cost – according to the initial budget BAC(1,X) – of the work that has actually been realized in X till the moment t;
- ACWP(t,X) – Actual Cost of Work Performed: the actual cost of the work that has actually been realized in X till the moment t;
- EAC(t,X) – Estimate at Completion: the predicted actual cost of the realization of X from the beginning till the end of the project; the prediction being done in the moment t. Of course, EAC(n,X) = ACWP(n,X) and EAC(1,X) = BAC(1,X).

The variances BCWP(t,X) – BCWS(t,X), called the Schedule Variance and BCWP(t,X) – ACWP(t,X), called the Cost Variance, are analysed in each control moment. The first variance shows the delays in the project realisation in respect to the initial schedule, the second one shows which elements of the project are being realised at a higher cost than it was supposed. But the key value delivered by the Earned Value Method in each moment $t, t = 1,\ldots,n$, is EAC(t,X). It is compared with BAC(t,X). If the latter is substantially smaller than the former, it means that problems are approaching – X, when it is finished and nothing really surprising happens – will not meet its budget. It is estimated using the following formulae:

a) Calculations for an individual activity $a_i \ (i = 1,\ldots m)$

Let us start with the following formula, a very general one:

$$EAC(t,a_i)=\begin{cases}BAC(1,a_i)\text{ if } a_i \text{ is unstarted}\\ ACWP(t,a_i)+ETC(t,a_i)\text{ otherwise}\end{cases} \tag{1}$$

where $ETC(t,a_i)$ is the estimated cost (estimated at the moment t) of the work that remains to be done from the moment t onwards within activity a_i.

Usually the following formula is used, which constitutes a special case of formula (1):

$$EAC(t,a_i)=\begin{cases}BAC(1,a_i)\text{ if } a_i \text{ is unstarted}\\ Ind_t(a_i)BAC(1,a_i)\text{ otherwise}\end{cases} \tag{2}$$

Formula (2) corresponds to the assumption that the total estimated cost of activity a_i being forecast at the moment t is equal to the cost initially planned multiplied by a factor which reflects changes with respect to the initially planned cost, where the changes are forecast in the moment t.

In the classical Earned Value Method $Ind_t(a_i)$ usually takes the following form:

$$Ind_t(a_i)=\frac{ACWP(t,a_i)}{BCWP(t,a_i)} \tag{3}$$

The above indicator assumes that if so far the work has been performed r times more expensively (cheaper) than it was planned, then the same factor can be applied to the total cost.

Let us assume that $X=\{a_{i_k}\}_{k=1}^{l}$ is a subset of P or P itself and that l>1. In this case the Earned Value Method proposes two ways of calculating EAC(t,X). The first method is based on the assumption about the mutual independence of activities belonging to X.

$$EAC(t,X)=\sum_{k=1}^{l}EAC(t,a_{i_k}) \tag{4}$$

The other method does not assume such an independence. The corresponding formula is:

$$EAC(t,X)=\begin{cases}BAC(1,X)\\ \text{if none act. in } X \text{ started;}\\ Ind_t(X)BAC(1,X)\text{ otherwise}\end{cases} \tag{5}$$

Formula (4) assumes that the total cost of X estimated in the moment t is equal to the sum of the estimated costs of all the activities constituting X. In formula (5) a global indicator of the forecast cost change, for the whole X, is used. This indicator is usually calculated according to the following formula:

$$Ind_t(X) = \frac{ACWP(t,X)}{BCWP(t,X)} = \frac{\sum_{k=1}^{l} ACWP(a_{i_k})S_{i_k}}{\sum_{k=1}^{l} BCWP(a_{i_k})S_{i_k}} \qquad (6)$$

where S_{i_k} takes on value 1 is activity a_{i_k} is started and 0 otherwise.

Thus, formula (5) used together with (6) combines all the changes in cost with respect to the initial plan that have occurred so far into one global indicator and applies them to the estimated cost at completion of the whole X.

There have been many discussions as to the practical usefulness of the above formulae. This discussion is presented e.g. in [6]. They concern the problem of how reliable the above formulae are real world cases, where there is lots of complexity and unexpectedness. However, we will not enter into this discussion, but propose an extension of the method, in order to enable it to take into account also other aspects, e.g. the delays in payments.

3. Revenues, cost, cash flows

It is well known that revenues and cost do not always equal cash flows in the same moment of time. As on the level of the whole company, also on the level of a single project it is necessary to control both aspects: the revenues (corresponding to the invoices made out by our enterprise within the respective period, irrespectively of the payment conditions) and cost (corresponding to the usage of resource within the respective period, irrespectively of the payment conditions) on one hand and the cash flows on the other.

Let us recall some basic relations between revenues, cost and cash flows. We will use the following notation: C -cost, R-revenue, Dep – depreciation, CI – cash inflow, CO – cash outflow, CF – cash flow (equal to CI-CO), AP – current accounts payable, L – current liabilities, S-stock of materials, ΔY – change in the value of Y within the given period.

If we consider only the level of a project and assume that there is no paid-in capital acquired thanks to the project and no stock of finished goods, we have the following dependencies:

$$CI=R-\Delta AP, \quad CO=C-Dep-\Delta L+\Delta S \qquad (7)$$

While preparing the project budget, we have to plan not only cost, but also the other elements of the above formulae. And then, during the project realisation, we have to control them. The Earned Value Method in its present form concerns only the control of cost. We propose to extend it in the way proposed in the next section.

4. Extension of the Earned Value Method

We propose to introduce into the method the following additional elements, first of all concerning the revenues:

- BRAC(t,X) – Budget of Revenues at completion: the whole budget of revenues that will be generated by X according to the information at the moment t. BRAC (1,X) is equal to the initially determined budget. In ideal conditions we would have BRAC(t,X) = BRAC (1,X) for each t;
- BRWS(t,X) – Budgeted Revenue of Work Scheduled: the revenue – according to the initial budget BRAC(1,X) – that should have been generated by the work that according to the initial schedule should have been realized in X till the moment t;
- BRWP(t,X) – Budgeted Revenue of Work Performed: the revenue – according to the initial budget BRAC(1,X) – that should have been generated by the work that has actually been realized in X till the moment t;
- ARWP(t,X) – Actual Revenue of Work Performed: the actual revenue generated by the work that has actually been realized in X till the moment t;
- ERAC(t,X) – Estimate of Revenue at Completion: the predicted actual revenue of the realization of X from the beginning till the end of the project; the prediction being done in the moment t.

The analysis of variances can be accomplished analogously to the analysis for costs. Also the calculation of ERAC(t,X) can be done in the same way.

However, it is also cash flows which are of importance. For them, the following magnitudes could be calculated:

- BcashAC(t,X) – Budget of cash at completion: the whole cash budget of X according to the information at the moment t. BcashAC(1,X) is equal to the initially determined budget which remains equal to BcashAC(t,X) throughout the whole project if no modifications are introduced;
- BCIWS(t,X) – Budgeted Cash Inflow of Work Scheduled: the cash inflow – according to the initial budget BcashAC(1,X) – that should have been generated by the work that according to the initial schedule should have been realized in X till the moment t;
- BCIWP(t,X) – Budgeted Cash Inflow of Work Performed: the cash inflow – according to the initial budget BcashAC(1,X) – that should have been generated by the work that has actually been realized in X till the moment t;
- ACIWP(t,X) – Actual Cash Inflow of Work Performed: the actual cash inflow generated by the work that has actually been realized in X till the moment t;
- ECIAC(t,X) – Estimate of Cash Inflow at Completion: the predicted total cash inflow of the realization of X according to information at moment t;
- BCOWS(t,X) – Budgeted Cash Outflow of Work Scheduled, defined analogously to BCIWS(t,X)
- BCOWP(t,X) – Budgeted Cash Inflow of Work Performed, defined analogously to BCIWP(t,X);

➢ ACOWP(t,X) – Actual Cash Outflow of Work Performed, defined analogously to ACIWP(t,X)

➢ ECOAC(t,X) – Estimate of Cash Outflow at Completion, defined analogously to ECIAC(t,X)

The variances here can be analysed in the same way as those concerning the cost in the classical Earned Value Method, also the calculation of ECOAC(t,X) and ECIAC(t,X) can be done similarly. However, the analysis of variances and the conclusions for the future may be more profound if we use the relationships presented in Section 3.

To make it clearer, let us take into account the equivalent of the cost variance from the classical Earned Value Method: BCIWP(t,X) – ACIWP(t,X). This is the difference between the cash inflows that should have happened for the work actually performed till moment *t* and the cash inflows that have actually happened. The difference between the two values may be due to various reasons and if we use relation (7), we can find out some of them in a relatively easy way. From (7) we have:

$$\begin{aligned} &BCIWP(t,X) - ACIWP(t,X) = \\ &(BRWP(t,X) - B\Delta APWP(t,X)) - (ARWP(t,X) - A\Delta APWP(t,X)) = \qquad (8) \\ &(BRWP(t,X) - ARWP(t,X)) - (B\Delta APWP(t,X) - A\Delta APWP(t,X)). \end{aligned}$$

where BΔAPWP(t,X) stands for Budgeted Change in Accounts Payable for Work Performed and AΔAPWP(t,X) stands for Actual Change in Accounts Payable for Work Performed.

The first component of the final form of (8), BRWP(t,X)-ARWP(t,X), will usually be due to changes in prices the customer pays. The second component, BΔAPWP(t,X) - AΔAPWP(t,X), will be due to the behaviour of customers - whether they pay as it was planned or not. The latter variance might be analysed further, if we present it in the following way:

$$\begin{aligned} &B\Delta APWP(t,X) - A\Delta APWP(t,X) = \\ &(B\Delta PerAPBP(t,X) - B\Delta PerAPAP) + (B\Delta PerAPAP - A\Delta PerAPAP(t,X)) \quad (9) \end{aligned}$$

where BΔPerAPBP(t,X) stands for Budgeted Change in the Percentage of Accounts Payable in Budgeted Prices (it is actually equal to BΔAPWP(t,X), the percentage refers to the percentage of the physical number of goods sold for which it was planned that the customers will not have paid till moment *t*), BΔPerAPAP stands for Budgeted Change in the Percentage of Accounts Payable in Actual Prices, AΔPerAPAP(t,X) is actually equal to AΔAPWP(t,X) and stands for Actual Change in the Percentage of Accounts Payable in Actual Prices - here the percentage refers to the physical number of goods sold for which the customers have not paid till moment *t*.

The first component of the final form of (9), BΔPerAPBP(t,X) – BΔPerAPAP, is due to the change in unit prices, but BΔPerAPAP – AΔPerAPAP(t,X) shows clearly to which extent the way the customers have paid has been different from what was planned.

A similar way of analysing further variances, e.g. BCOWP(t,X) – ACOWP(t,X) using (7), will show what influence on the variance in cash inflows the change in unit purchase prices has had, what the change in our behaviours as payers, what of the depreciation and what of the change of our stock policy.

Such a profound analysis of variances during the project realisation would make it possible to predict the final value of cash more accurately, so that as little surprises as possible await us at the closure of the project.

Conclusions

We have proposed to enhance the Earned Value Method by the analysis of variancec in cash flows, accounts payable, liabilities, stock level etc. The modified version of the method will fulfil to an even greater extent the first goal of the method: to be an efficient warning system, allowing to identify during the project realisation, before real problems occur or become visible to the external world (e.g. customers), problems and their reasons, indicating thus the aspects of the project realisation that should be changed or improved.

REFERENCES:

1. Joly M., Le Bissonnais J., Muller J.-L. G. (1995), Maîtriser le coût de vos projets, Afnor, Paris;

2. Dałkowski Tomasz B., Kuchta Dorota (2000): Szacowanie i kontrola kosztów w projektach. Monit. Rachun. Finans. 2000 no. 10 p. 58-65;

3. Dałkowski Tomasz B., Kuchta Dorota (2001): Klasyczna i zmodyfikowana metoda Earned value w zarządzaniu projektami, Badania Operacyjne i Decyzje(3/4), p.35-52;

4. EVMS - Earned Value Management Systems (1997), NSIA Management Systems Subcommitee;

5. Fleming Q.W., Hoppelman J.M. (1996), EARNED VALUE Project Management, Project Management Institute;

6. Kuchta Dorota (2005), Fuzzyfication of the earned value method. WSEAS Trans. Syst. 2005 vol. 4 iss. 12 p. 2222-2229.

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