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Barbara GŁADYSZ*
Dorota KUCHTA*

# ESTIMATION OF LONG-TERM PROJECT RISK DURING PROJECT REALIZATION – COMBINATION OF THE EARNED VALUE AND PRESENT VALUE METHODS

The paper proposes a combination of two methods: the Net Present Value Method and the Earned Value Method – to control the risk of not achieving the targeted value of long-term projects. The method is capable, like the Earned Value Method, to forecast future financial overruns ahead of time and to warn the project manager long before the event itself occurs so that the project manager has time to handle the problem. On the other hand, the proposed method is able, like the Net Present Value, to take the time value of money into account.

Keywords: *Net Present Value Method, Earned Value Method, Project, Risk*

## 1. Introduction

Each project is linked to a risk – this is a well known truth. Therefore, there are a lot of methods of project risk management e.g. [4], comprising risk management planning before the project realization and risk management execution during the project realization. It seems, however, that in practice the second phase is a bit neglected with respect to the first one: during the project realization everyone is usually very busy and there is no time for project risk management. Often the consequences of this attitude are serious: the project does not succeed. That is why project risk management methods for the project realization phase should be as simple as possible but effective, at least in most cases. The Earned Value Method is such a method [1] – in spite of its numerous drawbacks [3], it has been widely accepted in practice. How-

* Instytytut Organizacji i Zarządzania Politechniki Wrocławskiej, ul. Smoluchowskiego 25, 50-372 Wrocław, e-mail: Barbara.Gladysz@pwr.wroc.pl, Dorota.Kuchta@pwr.wroc.pl

ever, it is not appropriate for long-term projects since it does not take into account the time value of money. Therefore, we propose here a modification of this method, which will be suitable for long-term projects. It will make use of the Net Present Value concept.

First, we will explain the classic Earned Value Method, then the Net Present Value Method, and finally their combination: the modification of the Earned Value Method which is the object of the paper. A computational example will conclude the paper.

## 2. Classical Earned Value Method

The classical Earned Value Method has been widely accepted as a tool of estimating and controlling project cost risk during the project realization. The method is supposed to be simple and quick in use and deliver an overall risk estimation, without entering into too complex and sophisticated estimation and information collecting methods. Here is a description of its basic elements:

Let us consider a project *P*, being a set of tasks (activities) $\{A_j, j = 1, ..., n\}$, scheduled for a period $T_s$, in which time units $t = 0, 1, 2, ..., T_s - 1, T_s$ can be distinguished. These are the smallest units which it is sensitive to consider. The actual project duration will be denoted as $T_A$.

In the Earned Value Method we distinguish the following notions (the upper index *P* stands for project, the upper index $A_j, j = 1, ..., n$ stands for the individual activity):

- $BAC^P$ $(BAC^{A_j})$ – Budgeted at Completion: the total amount of work to be done in the project (activity) (expressed in certain units, maybe in hours, meters, square meters, etc.) multiplied by the planned cost of completing one unit of work[1];
- $BCWS^P(t)$ $(BCWS^{A_j}(t))$ – Budgeted Cost of Work Scheduled in a moment *t*, $t = 1, 2, ..., T_s - 1, T_s$: the work in the project (activity) that has been scheduled to be done till moment *t*, multiplied by the planned cost of completing one unit of work; if $T_A > T_S$ then $BCWS^P(t) = BAC^P$ $(BCWS^{A_j}(t) = BAC^{A_j})$ for $T_S \le t \le T_A$;
- $BCWP^P(t)$ $(BCWP^{A_j}(t))$ – Budgeted Cost of Work Performed in a moment *t*, $t = 1, 2, ..., T_A - 1, T_A$: the work in the project (activity) that has actually been done till moment *t*, multiplied by the planned cost of completing one unit of work;

[1] Or a sum of such multiplications, if there are items of work measured in different units or having different unitary cost.

- $ACWP^P(t)$ $(ACWP^{A_j}(t))$ – Actual Cost of Work Performed in a moment $t$, $t = 1, 2, ..., T_A - 1, T_A$: the work in the project (activity) that has actually been done till moment $t$, multiplied by the actual cost of completing one unit of work;
- $EAC^P(t)$ $(EAC^{A_j}(t))$ – Estimated Cost at Completion in a moment $t$, $t$ = 1, 2, ..., $T_A$ – 1, $T_A$: the cost of the total of work to be done in the project (activity) estimated in the moment $t$, it is meant to be a forecast, based on the information available so far – a forecast updated in each control moment $t$.

The difference $EAC^P(t) - BAC^P$ is a measure of the risk of overrunning the budget, once the project is terminated, measured at the moment $t$. The whole problem consists in the question how to calculate $EAC^P(t)$ $(EAC^{A_j}(t))$. As the Earned Value Method is supposed to be a simple, unsophisticated method, usually one of two assumptions is made:

A1. If the actual average unitary cost in the project or in an already started task has been different so far from the budgeted one, the ratio of the two will be maintained in the future.

A2. Even if the actual average unitary cost in the project or in an already started task has been different so far from the budgeted one, in the future the budgeted cost will occur.

Usually A1 is assumed, as the experience shows that in most projects the budget is exceeded and on the average – if the cost has been greater than expected so far – it is better to make a more pessimistic assumption. If A1 is assumed, then we have:
either

$$EAC^P(t) = \frac{ACWP^P(t)}{BCWP^P(t)} BAC^P \tag{1}$$

or

$$EAC^P(t) = \sum_{j \in S} \frac{ACWP^{A_j}(t)}{BCWP^{A_j}(t)} BAC^{A_j} + \sum_{j \in NS} BAC^{A_j} \tag{2}$$

where $S$ represents the indices of those activities which have been started already (finished or not) and $NS$ the indices of those activities which have not been started yet. Some formulae for $EAC$ [1] do make use of $BCWS$, when they try do take into account the influence of the delay in the work execution on costs. But these formulae are very rough and with the modification proposed in Section 4 they would not be necessary any more.

Of course, (1) and (2) yield different results: (1) applies the ratio of the average actual cost that has occurred so far to the planned cost to the whole project, (2) treats each activity individually and assumes that those activities which have not been started yet cannot be assumed to be more expensive than planned only because some previous activities have been such.

This method has turned out to be very useful from the practical point of view, in spite of its simplicity in estimating future cost. It is an efficient warning system, which warns against a cost overrun before this overrun actually takes place (the difference $EAC^P(t) - BAC^P$ is not an actually occurred value, it is only a value which may become a reality in the future if we do not change anything; $EAC^P(t)$ may be different in each control moment $t$).

Exactly the same approach might be applied to projects which generate not just cost, but also revenues and net incomes. However, if we consider a long-term project, the Earned Value might deliver wrong information, because it does not take into account the time value of money. It disregards the moment when individual cost/expenditures and revenues should have and will actually take place. This may be fine if short-term projects are considered. However, if we consider projects whose realization goes on for several years, the time factor should be taken into account. For this case we will propose a modification of the Earned Value Method. But before doing so, let us recall the way the time value of money may be taken into account in project management.

## 3. Net Present Value Method

Let us consider a project in which the cash flows (positive – inflows, negative – outflows, or both) take place (or are planned to take place) in time units $t = 0, 1, 2, ..., T-1, T$. Let us denote them by $CF_t$. Then the value of the project is estimated in the moment 0 as its Net Present Value (abr. NPV), defined as

$$\text{NPV} = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \tag{3}$$

where $r$ is a discount rate, which corresponds to the loss we incur because of waiting for one time unit for the cash flow, if it is positive, and the gain we incur waiting to spend it for one time unit, if it is negative (details can be found, e.g., in [2]).

Thanks to the discounting applied in (3) we get rid of the time influence on money – we evaluate the project in terms of monetary units in time 0 or in any other selected moment. We can then compare project planned for 20 years with those planned for 5 years. And if there are some changes as far as the moments of the individual cash flow occurrence are concerned, the corrected NPV would take them into account.

In the following section we propose a combination of the Earned Value Method with NPV, such that the Earned Value Method is useful also for long-term projects.

## 4. Modification of the Earned Value Method – combination with the Net Present Value Method

We assume that we consider a project where we have no receipts, just costs (expenditures), and that they are incurred at the end of the respective periods. An extension to the case of receipts (incomes) would be straightforward. Let us define the following notions:

- $BCWS^P(t-1,t)$ $(BCWS^{A_j}(t-1,t))$ – Budgeted Cost of Work Scheduled in a period $[t-1,t)$, $t=1,2,...,T_s-1,T_s$: the work in the project (activity) that has been scheduled to be done between moment $t$ – 1 and $t$, multiplied by the planned cost of completing one unit of work; if $T_A > T_S$ then $BCWS^P(t-1,t)=0$ $(BCWS^{A_j}(t-1,t)=0)$ for $T_S+1 \le t \le T_A$.
- $BCWP^P(t-1,t)$ $(BCWP^{A_j}(t-1,t))$ – Budgeted Cost of Work Performed in a period $[t-1,t)$, $t=1,2,...,T_A-1,T_A$: the work in the project (activity) that has actually been done between moment $t$ – 1 and $t$, multiplied by the planned cost of completing one unit of work;
- $ACWP^P(t-1,t)$ $(ACWP^{A_j}(t-1,t))$ – Actual Cost of Work Performed in a period $[t-1,t)$, $t=1,2,...,T_A-1,T_A$: the work in the project (activity) that has actually been done between moment $t$ – 1 and $t$, multiplied by the actual cost of completing one unit of work;
- $BNPV^P$ (Budgeted Net Present Value): equal to $\sum_{t=1}^{T_S} \frac{BCWS^P(t-1,t)}{(1+r)^t}$;
- $ENPVC^P(t)$ – Estimated NPV at Completion in a moment $t$, $t$ = 1, 2, ..., $T_A$ – 1, $T_A$: the NPV of the whole project estimated in the moment $t$.

The measure that will express (during the execution of the project) the risk of the final NPV to be significantly "worse" (in the case of a project which generates only costs "worse" means ("bigger") that the budgeted one will be the difference $BNPV^P$ – $ENPVC^P(t)$. The problem is how to calculate $ENPVC^P(t)$. Since this is a value which is an estimation, again – as in the case of $EAC$ – there will be several ways of calculating it, and again the various ways will correspond to various assumptions. We might also consider formulae analogous to (2), where individual activities are treated individually, but here we will assume that we want to treat the whole project identically.

We will have to make two assumptions. The first one has to be chosen from the following ones:

B1. We want to finish the project in the planned time, independently of whether we have had a delay or an advance so far (thus we will do the work at a higher or smaller pace than so far, correspondingly to the case);

B2. We will finish the project in a moment which will be a function of the pace we have had so far – in the case of a delay we will finish it later than planned and in the case of an advance – earlier.

The second group of assumptions is a generalization of assumptions A1 and A2, it is possible to introduce a third assumption because of our approach in which we distinguish individual periods.

C1. In the future the ratio of average actual cost and average planned cost will be as in the past;

C2. In the future the ratio of average actual cost and average planned cost will be as in a selected period in the past;

C3. In the future the planned cost should be assumed.

The third group of assumptions is similar to the second one, but it concerns the pace of work. These assumptions will enter into the game only if assumption B2 is made.

D1. In the future the pace of work will be as in the past;

D2. In the future the pace of work will be as in a selected period in the past;

D3. In the future the planned pace of work should be assumed.

Let us consider the combination of assumptions B1 and C1. With assumption B1 we assume that we want to finish the project in the planned moment $T_S$. But we assume also that we will keep the proportions of work to be done planned for the individual periods in the future. Then we will have:

$$ENPVC^P(t) = \sum_{s=1}^{t} \frac{ACWP^P(s-1,s)}{(1+r)^s} + \sum_{s=t+1}^{T_S} \left[ \frac{WR^P(s)}{(1+r)^s} \frac{BCWS^P(s-1,s)}{\sum_{w=t+1}^{T_S} BCWS^P(w-1,w)} \right] CC^P(t) \quad (4)$$

where

$WR^P(t) = BAC^P - \sum_{s=1}^{t} BCWP^P(s-1,s)$ is the work remaining in moment $t$, expressed in the budgeted cost,

$CC^P(t)$ is the cost coefficient for the project, expressing the ratio of the actual cost and the planned cost so far, according to assumption C1 it is defined as

$$CC^P(t) = \frac{\sum_{s=1}^{t} ACWP^P(s-1,s)}{\sum_{s=1}^{t} BCWS^P(s-1,s)} . \tag{5}$$

If we choose assumptions B1 and C2, formula (4) is still valid, the only change will concern $CC^P(t)$: in (5) the summation will be only over the period which has been chosen as the representative one.

If we choose assumptions B1 and C3, we will have the following formulae:

$$ENPVC^P(t) = \sum_{s=1}^{t} \frac{ACWP^P(s-1,s)}{(1+r)^s} + \sum_{s=t+1}^{T_S} \left[ \frac{WR^P(s)}{(1+r)^s} \frac{BSWS^P(s-1,s)}{\sum_{w=t+1}^{T_S} BCWS^P(w-1,w)} \right] . \tag{6}$$

If we choose assumption B2, C1 and D1, we will have:

$$ENPVC^P(t) = \sum_{s=1}^{t} \frac{ACWP^P(s-1,s)}{(1+r)^s} + \sum_{s=t+1}^{T_A} \left[ \frac{WR^P(s)}{(1+r)^s} \right] \frac{CC^P(t)}{T_A - t} \tag{7}$$

where $T_A$ is calculated on the basis of the average pace kept so far:

$$T_A = t + \frac{WR^P}{P^p(t)} \tag{8}$$

where

$$P^p(t) = \frac{\sum_{s=1}^{t} BCWP^p(s-1,s)}{t} \tag{9}$$

is the average pace so far and $CC^P(t)$ is calculated according to (5), or, if assumption C1 is replaced with C2, the summation will be done over the selected period.

If assumption D1 is replaced with D2 (i.e. we assume B2, C1, D2), formula (9) will be modified accordingly. If assumptions B2, C1 and D3 are selected, we will have the following formula:

$$ENPVC^P(t) = \sum_{s=1}^{t} \frac{ACWP^P(s-1,s)}{(1+r)^s} + \sum_{s=t+1}^{T_A-1} \left[ \frac{BCWS^P(s-1,s)}{(1+r)^s} \right] CC^P(t) + R \tag{10}$$

where

$$R = BAC^P - \left( \sum_{s=1}^{t} BCWP^P(s-1,s) + \sum_{s=t+1}^{T_A} BCWS^P(s-1,s) \right) \tag{11}$$

and $T_A$ is the highest integer number such that

$$\sum_{s=1}^{t} BCWP^P(s-1,s) + \sum_{s=t+1}^{T_A} BCWP^P(s-1,s) \le BAC^P \,. \tag{12}$$

For the missing combinations of assumptions: (B2, C2, D1), (B2, C2, D2), (B2, C2, D3), (B2, C3, D1), (B2, C3, D2), (B2, C3, D3), the corresponding formulae are straightforward.

To sum up, let us put together all the assumptions combinations (assumption from the D group enter into consideration only if assumption B2 is made):

| Combination | Description |
|---|---|
| (B1, C1) | We want to finish the project in the planned time, in the future the ratio of the average actual cost and the average planned cost will be as in the past, in the future the pace of work will be as in the past. |
| (B1, C2) | We want to finish the project in the planned time, in the future the ratio of the average actual cost and the average planned cost will be as in a selected period in the past, in the future the pace of work will be as in the past. |
| (B1, C3) | We want to finish the project in the planned time, in the future the planned cost should be assumed, in the future the pace of work will be as in the past. |
| (B2, C1, D1) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the ratio of the average actual cost and the average planned cost will be as in the past, in the future the pace of work will be as in the past. |
| (B2, C1, D2) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the ratio of average actual cost and average planned cost will be as in the past, in the future the pace of work will be as in a selected period in the past. |
| (B2, C1, D3) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the ratio of the average actual cost and the average planned cost will be as in the past, in the future the planned pace of work should be assumed. |

| | |
|---|---|
| (B2, C2, D1) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the ratio of the average actual cost and the average planned cost will be as in a selected period in the past, in the future the pace of work will be as in the past. |
| (B2, C2, D2) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the ratio of the average actual cost and the average planned cost will be as in a selected period in the past, in the future the pace of work will be as in a selected period in the past. |
| (B2, C2, D3) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the ratio of the average actual cost and the average planned cost will be as in a selected period in the past, in the future the planned pace of work should be assumed. |
| (B2, C3, D1) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the planned cost should be assumed, in the future the pace of work will be as in the past. |
| (B2, C3, D2) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the planned cost should be assumed, in the future the pace of work will be as in a selected period in the past. |
| (B2, C3, D3) | We want to finish the project in a moment which will be a function of the pace we have had so far, in the future the planned cost should be assumed, in the future the planned paste of work should be assumed. |

## 5. Computational example

Let us consider the following long-term project: it is planned for the period of 10 years, payments are done at the end of each year. The scope of the project is to make 10 items of a certain good – one item each year. The planned cost of each item is \$, thus $BAC^P$ = 30 \$, $BCWS^P(t-1,t) = 3\,\$\ (t = 1, 2, ..., 10)$. Let us suppose that each year the cost of capital is 20%, thus $r$ = 0.2, then $BNPV^P$ = $\sum_{t=1}^{10} \frac{3}{(1+0.2)^t} = 12.58$.

Let us suppose that the realization of the project is controlled at the end of the 3rd year. It is then stated that instead of 3 items planned, only 2 have been manufactured, and each one costs 4 \$. More exactly, during the 1st year 1 item was manufactured and during the following two years another one. Thus we have:

$$BCWP^P(0.1) = 3\ \$, BCWP^P(1.2) = 1.5\ \$, BCWP^P(2.3) = 1.5\ \$$$

$$ACWP^P(0.1) = 4\ \$, ACWP^P(1.2) = 2\ \$, ACWP^P(2.3) = 2\ \$.$$

Let us now suppose that we are dealing with the case where assumptions B1 and C1 can be made. Then we have from (4):

$$ENPVC^P(3) = \frac{4}{(1+0.2)} + \frac{2}{(1+0.2)^2}\frac{2}{(1+0.2)^3} + \sum_{s=4}^{10}\left[\frac{24}{(1+0.2)^s}\frac{1}{7}\right]\frac{4}{3} = 15.42.$$

Thus, at the end of the 3rd year there is a risk that the NPV of the cost of the project will be higher by more than 20%. This is much – it depends on the financial situation of the decision maker, whether he is ready to accept this or not. If not, he has time to try to solve the problem. Because the most important thing is that we have a forecast, a warning of a value which will occur only in seven years – we are estimating the NPV of a 10 year project at the end of the 3rd year!

Let us now suppose we are dealing with another project – one for which we can make the assumptions B2, C1, D1. than we have from (7), (8), (9):

$$P^p(3) = \frac{3+1.5+1.5}{3} = 2$$

$$T_A = 3 + \frac{24}{2} = 15$$

$$ENPVC^P(3) = \frac{4}{(1+0.2)} + \frac{2}{(1+0.2)^2} + \frac{2}{(1+0.2)^3} + \sum_{s=4}^{15}\left[\frac{24}{(1+0.2)^s}\right]\frac{\frac{4}{3}}{12} = 12.73.$$

We can see that in this case the risk of NPV being exceeded is much lower, almost negligible. Thus, we do not have to undertake any steps, it seems that the execution of the project is going on well.

## Conclusions

We have proposed a combination of the Earned Value and Net Present Value methods, creating a method which will help, during a long-term project realization, to estimate the risk that once the project is finished, the actual NPV of the project cash flows will be significantly worse that initially estimated. It is important that this will be known before the fact has already occurred – it will be a warning system allowing to undertake some steps to prevent the negative fact from happening.

In the paper we have discussed only the projects which generate just costs, but a generalization to projects with revenues would be straightforward.

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## Wyznaczanie poziomu ryzyka podczas realizacji projektów długookresowych – kombinacja metod wartości uzyskanej i wartości własnej netto

Z każdym projektem związane jest ryzyko – to ogólnie znana prawda. Opracowano więc wiele metod zarządzania ryzykiem projektu w zakresie planowania ryzyka przed rozpoczęciem projektu oraz zarządzania ryzykiem podczas jego realizacji. Wydaje się, że w praktyce ten drugi etap w odniesieniu do pierwszego jest trochę zaniedbywany, gdyż podczas realizacji projektu wszyscy są bardzo zaangażowani i nie mają czasu na zarządzanie ryzykiem. Konsekwencje takiego podejścia są często niezwykle groźne. Projekt nie kończy się sukcesem. Dlatego też metody zarządzania ryzykiem projektu w fazie jego realizacji powinny być tak proste jak to tylko możliwe, ale zarazem efektywne. Taką metodą jest metoda wartości uzyskanej (*Earned Value*). Pomimo słabej strony obliczeniowej jest ona często stosowana w praktyce. Nie jest to jednak właściwa metoda dla projektów długoterminowych, gdyż nie uwzględnia się w niej zmiany wartości pieniądza w czasie. Proponujemy zatem modyfikację, która metodę tę uczyni przydatną dla projektów długoterminowych. Uwzględniamy przy tym koncepcję metody wartości własnej netto (*Net Present Value*).

W pracy przedstawiono klasyczną koncepcję metody wartości uzyskanej i metody wartości bieżącej netto, a następnie ich kombinację: modyfikację metody wartości uzyskanej, która jest tematem tego artykułu. Zaprezentowano przykład obliczeniowy.

Słowa kluczowe: *teraźniejsza wartość netto, metoda wartości wypracowanej, projekt, ryzyko*