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EV WITH DURATION FORECASTING. CASE STUDY

PRZYKŁAD ZASTOSOWANIA EV WRAZ Z PROGNOZĄ TERMINU KOŃCOWEGO

A b s t r a c t

This paper presents development of the earned value concept regarding forecasting project duration time. On the basis of the calculations carried out for an implemented investment project, consisting of development of the sanitary sewage and municipal water supply system, individual methods and their assumptions were presented and discussed.

Keywords: EV, duration forecasting, ES, PV, ED

S t r e s z c z e n i e

W artykule przedstawione zostało rozwinięcie wartości wypracowanej w aspekcie prognozowania terminu końcowego realizacji. Na podstawie obliczeń przeprowadzonych dla zrealizowanej inwestycji obejmującej swoim zakresem rozbudowę kanalizacji sanitarnej i wodociągu wiejskiego przedstawione i omówione zostały poszczególne metody i ich założenia.

Słowa kluczowe: EV, prognozowanie, ES, PV, ED

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1. Introduction

Earned Value (EV) or, more broadly, Earned Value Management is a technique used to monitor project implementation progress. This method combines the possibility of verification of the schedule scope and the cost of tasks in the project. The methodology was introduced in the 1960's by the United States Department of Defense. The aim was to obtain the full scope of knowledge on all projects financed by the state budget and effectiveness of the funds spent on these [3]. The method was based on planned value (PV), actual cost (AC) and earned value (EV) which allows for determining the rate of project advancement, detecting any delays or the possibility of exceeding the budget, while specifying the causes. On the basis of the data above, it is possible to determine cost variance (CV), schedule variance (SV), schedule performance index (SPI) and the Cost Performance Index (CPI). In 1998, official ANSI/EIA-748 standards and guidelines were published [1] for the purpose of popularizing the method both in public and private procurement procedures. Since then, many publications dedicated to this methodology have become available. The aspects, in which the methodology is subject to development, have been divided by the author of this article into several groups:

- Method of determination of the quantity of works performed and the accuracy of data influence on the correctness of calculations made. In literature, there are many approaches to this issue which have been described, proposing that values are expressed as percentages, e.g. in the proportion of 50/50, 0/100 analyzed by [6], 10/90, 20/80, 25/75, and the recently proposed method for determining the quantity of works performed using the fuzzy-logic method [8];
- Tools and applications. The calculation-supporting tools that have been proposed include: MS Project, Primavera 6, Developed Software [13] and Pro track [20];
- Final cost forecasting. This issue has been discussed in many publications, including [5], [6], [12, 19];
- Final schedule forecasting. Many calculation methods are proposed and developed in the literature, including the following publications: [2, 4, 8, 10, 11, 15].

This article focuses on the last issue. Research conducted so far [2, 4, 8, 10, 11, 15] indicates that on the basis of current project inspections and emerging trends, it is possible to forecast the project completion date with a high level of accuracy.

After a review of the studies quoted above, calculations were conducted for a completed facility constructed in Lesser Poland (małopolskie).

2. Calculation example

Calculations were conducted using an investment project, completed in the period between December 2011 and January 2013 as an example. The investment scope included the construction of a domestic sewage system with a high pressure pumping station, a power generator building with a water supply line to the pumping station and a power supply, an access road to the pumping station, as well as relocation of an existing water supply pipeline, ditch bridging and finally, laying a rainwater sewage line culvert in the ditch. The agreement between the contractor and the investor was signed on the basis of a quantity survey. The

Table 1

The EVM system parameters for the example being analyzed (source: own work)

Par	Duration													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PV	83 003	198 146	405 463	503 024	746 927	974 569	1275382	1576195	1828228	2023350	2072130	2129041	2199140	2416637
%	3,43%	8,2 0%	16,78%	20,82%	30,91%	40,3 3%	52,7 8%	65,2 2%	75,6 5%	83,7 3%	85,7 4%	88,1 0%	91,0 0%	100%
EV	83 018	295 350	444 895	663 233	876 811	1070727	1299499	1514871	1680354	1977133	2124807	2277551	2319972	2370103
%	3,4 4%	12,22%	18,41%	27,44%	36,28%	44,3 1%	53,7 7%	62,6 9%	69,5 3%	81,8 1%	87,9 2%	94,2 4%	96,0 0%	98,0 7%
AC	98 787	342 327	504 677	742 999	958 705	122 6926	1404207	1503336	1618816	1749325	1904149	2008181	2127824	2167310
SV	16	97 204	39 432	160 209	129 884	96 158	24 117	–61 325	–147 874	–46 217	52 677	148 510	120 832	–46 534
SV%	0, 0%	49, 1%	9, 7%	31, 8%	17, 4%	9, 9%	1, 9%	–3, 9%	–8, 1%	–2, 3%	2, 5%	7, 0%	5, 5%	–1, 9%
CV	–15 769	–46 977	–59 782	–79 766	–81 893	–156 199	–104 708	11 534	61 538	227 808	220 658	269 370	192 148	202 794
CV%	–19, 0%	–15, 9%	–13, 4%	–12, 0%	–9, 3%	–14, 6%	–8, 1%	0, 8%	3, 7%	11, 5%	10, 4%	11, 8%	8, 3%	8, 6%
CPI	0,84	0,86	0,88	0,89	0,91	0,87	0,93	1,01	1,04	1,13	1,12	1,13	1,09	1,09
SPI	1,00	1,49	1,10	1,32	1,17	1,10	1,02	0,96	0,92	0,98	1,03	1,07	1,05	0,98

planned investment value was about PLN 2 420 000, and the planned duration time was 14 months.

During implementation, financial settlements were carried out and measurement cards were prepared on a monthly basis, which specified in detail, the quantity and progress of all types of works. Calculations using EV was conducted on the basis of data received from the contractor, upon completion of the investment project. The results of EV calculations are presented in table 1.

Assumptions made for calculation purposes:

- PV. The planned progress of works, while planned costs were determined on the basis of the schedule of works and expenditures, agreed upon with the Investor;
- EV. The actual progress of works was determined on the basis of measurement cards for individual cost estimate items;
- AC. The real costs incurred in the settlement periods, taking into account the direct construction costs established on the basis of the invoices and settlement protocols, and indirect costs.

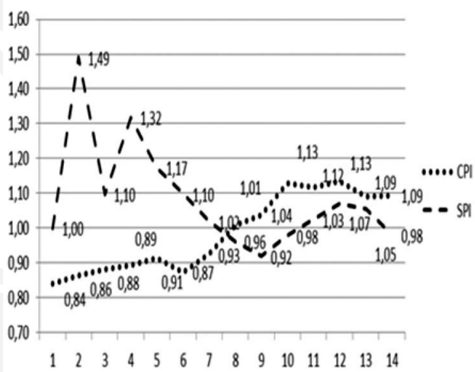

Fig. 1. SPI and CPI value (source: own work)

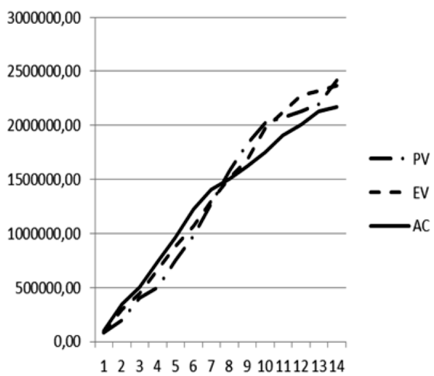

Fig. 2. BCWS, BCWP, ACWP chart (source: own work)

The values of selected indices applied in the EVM method are interpreted as follows:

- CPI, SPI > 1 performance below the cost planned, faster than planned; < 1 above the budget planned, slower than planned; = 1 accordingly with the cost and schedule planned.
- Since the calculation results, obtained so far, serve as a basis for further analysis, the author has summarized these in three short points:
- SPI, CPI. Early months of performance – work was conducted at a much faster pace, while higher costs were incurred. Months 8–10 – a delays were recorded, but the SPI value remained high at > 0,9. During the following months – until the end, the facility was completed at a faster pace than planned and at a lower costs (Fig. 1).
- The time planned for completion of the project took longer than needed. This resulted in performance of works in steps. Sometimes, the Contractor accelerated the works to complete a given stage, or delayed the commencement of another stage of works.
- The facility was constructed by the contractual deadline below the budget planned. The scope turned out to be 2% lower than planned (about PLN 46 000). The total profit from the project amounted to PLN 200 000, which constitutes to more than 9% of the value of all works performed (Fig. 2).

3. Final schedule forecasting

All EV parameters have been expressed in monetary units, including schedule variance (SV) and schedule performance index (SPI). In addition, the calculations and analyses quoted in literature suggest that the values of both indices for the final period of project implementation assume erroneous values [4, 10]. These difficulties have led to emergence and development of the following methods used to forecast the final schedule: the planned value method [2], the earned duration method [8] and the earned schedule method [10]. Each of these methods can be used under the following circumstances:

- The final project schedule will be as planned, regardless of progress of the project in the past;
- The planned schedule for completion of the remaining works is unattainable due to a change in the conditions – a new schedule should be established for these;
- The date of completion of the remaining works is much delayed; due to technical problems, successful completion of the project becomes highly questionable;
- The remaining works will be completed as planned; progress of works in the past will be of no impact upon these;
- Progress of works in the past will impact on future works, which will be adapted to the current conditions;
- Progress of works in the past (both the cost and the time) will exert an impact upon the remaining works ($CR = SCI = SPI \times CPI$).

The author decided to conduct calculations for the last three variants in accordance with the suggestions provided in the study [15], and applied the standardized nomenclature, proposed by the authors of the study. Formulas for individual variants in individual approaches have been presented in Table 2.

Table 2

A breakdown of calculation formulas for determination of the final schedule EAC(t)
(source: own work)

Estimate at Completion EAC(t)		
Index	Calculation formula	Approach
Anbari, The planned value method, 2003		
EAC(t)PV1	EAC(t)PV1 = SAC – TV	Duration of remaining work as planned
EAC(t)PV2	EAC(t)PV2 = PD/SPI	Duration of remaining work follows the current SPI trend
EAC(t)PV3	EAC(t)PV3=PD/SCI	Duration of remaining work follows the current SCI trend
	TV =SV/PVRate = (SV*PD) / BAC = (EV–PV)* PD/BAC	
	PVRate = BAC/PD	
CR/SCI	CSI = CPI*SPI	
Jackob and Kane, The earned duration method, 2003		
AD<PD	EAC(t)ED = AD + (PD-ED)/PF	
AD>PD	EAC(t)ED = AD + (AD-ED)/PF	
EAC(t) ED1	EAC(t)ED1 = AD + (PD-ED)/1=PD + AD*(1-SPI)	Duration of remaining work as planned; PF = 1
EAC(t) ED2	EAC(t)ED2 = AD + (PD-ED)/SPI=PD/SPI	Duration of remaining work follows the current SPI trend; PF = SPI
EAC(t) ED3	EAC(t)ED3 = AD + (PD-ED)/SCI = PD/SCI + AD*(1-1/CPI)	Duration of remaining work follows the current SCI trend; PF = SCI
	ED = AD*SPI	
Lipke, The earned schedule method, 2004		
	EAC(t)ES = AD + (PD-ES)/PF	
EAC(t) ES1	EAC(t)ES1 = AD + (PD-ES)/1 = AD + (PD-ES)	Duration of remaining work as planned; PF = 1
EAC(t) ES2	EAC(t)ES2 = AD + (PD-ES)/SPI (t)	Duration of remaining work follows the current SPI trend; PF = SPI(t)
EAC(t) ES3	EAC(t)ES3 = AD+(PD-ES)/(CPI*SPI(t)) = AD + (PD-ES)/SCI(t)	Duration of remaining work follows the current SCI trend; PF = SCI(t)
	ES = N + (EV-PVn)/(PVn + 1 – PVn)	
	SPI(t) = ES/AT	
	SCI(t) = CPI*SPI(t)	

Table 3

Breakdown of EAC (t) value on the basis of the proposed calculation methods (source: own work)

PD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PV1	14,0	13,4	13,8	13,1	13,3	13,4	13,9	14,4	14,9	14,3	13,7	13,1	13,3	14,3
PV2	14,0	9,4	12,8	10,6	11,9	12,7	13,7	14,6	15,2	14,3	13,7	13,1	13,3	14,3
PV3	16,7	10,9	14,5	11,9	13,0	14,6	14,9	14,5	14,7	12,7	12,2	11,5	12,2	13,1
ED1	14,0	13,0	13,7	12,7	13,1	13,4	13,9	14,3	14,7	14,2	13,7	13,2	13,3	14,3
ED2	14,0	9,4	12,8	10,6	11,9	12,7	13,7	14,6	15,2	14,3	13,7	13,1	13,3	14,3
ED3	16,5	10,6	14,1	11,4	12,6	13,7	14,3	14,5	15,0	13,8	13,4	13,0	13,2	14,3
ES1	14,0	13,5	13,6	13,3	13,4	13,7	13,9	14,2	14,8	14,9	13,1	11,9	14,2	15,2
ES2	14,0	11,3	12,3	12,0	12,6	13,3	13,8	14,4	15,3	15,5	12,9	11,9	14,2	15,3
ES3	16,5	11,0	14,0	11,9	12,9	14,0	14,3	14,4	15,0	14,5	12,8	11,9	14,0	15,1

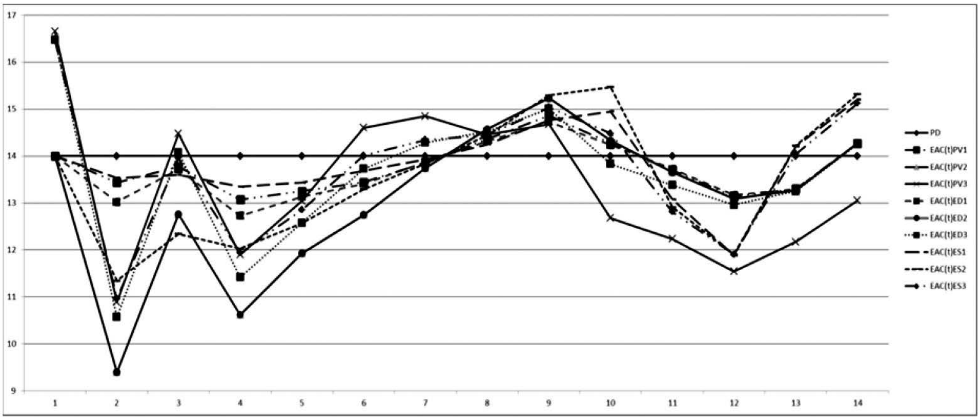

Fig. 3. Chart of results for EAC (t) developed on the basis of Table 3 (source: own work)

The calculation results [see Table 3] indicate a relatively significant discrepancy in the value of EAC(t) obtained on the basis of individual formulas:

- The most significant discrepancy can be observed after 1/3 of the Project duration; forecast time ranges from 9 to 17 months.
- After 2/3 of the project duration, results stabilized at a level similar to the project duration time (actual and planned).
- EAC(t) ED2 and EAC(t) PV2 results assume the same values.
- The least reliable results were observed for formulas EAC(t) ES2 and EAC(t) ES3.
- Results closest to actual values were observed in the case of EAC(t) PV1, EAC(t) ED1 and EAC(t) ES1.

- Fluctuations of the EAC(t) curves can be observed in those locations, in which substantial deviation of the actual progress of works occurred in relation to the baseline plan.

4. Conclusions

On the basis of the calculations performed, the author observed the following regularities:
- The analysis indicates positive results for the EV method, as a tool for project controlling in terms of the costs incurred and progress of works;
- The results of the final schedule forecasts are not reliable during the early phase of the project (1/3), they stabilize in the middle, and only in the final phase of the project, become highly probable;
- In the example presented, the results were obtained for all methods using the approach „performance as planned" – which is not consistent with information provided in the literature [11, 15], in which the Earned Schedule (ES) obtains the most reliable results in most of the cases analyzed;
- Disturbing the planned progress of works due to temporary acceleration and delaying of works exert significant impact on correctness of the forecast results.

The calculations performed do not conclusively prove the correctness of the formulas applied. In the case analyzed, the approach „project performer as planned" attained the results closest to the actual values in each of the proposed methods [2, 8, 10]. The ES results, unlike in the examples quoted in literature [11, 15], differed most from the actual values. Such results may be obtained in a situation, in which it is assumed in advance that the planned performance period would not be changed, and works would be delayed or accelerated only temporarily. Such performance of works in steps results in forecast errors; assumptions made in order to meet the deadline established in the forecast, in accordance with the plan. The analysis conducted has confirmed this assumption.

The issue of forecasting should be developed further in order to obtain more accurate information, confirmed by analysis using a greater number of exemplary projects, carried out under varied conditions, taking the mode and accuracy of the data collected into account.

References

[1] American National Standards Institute, *Earned Value Management Systems*, ANSI/EIA-748-A-1998, 1998.

[2] Anbari F., *Earned value method and extensions*, Project Manage J, 34 (4), 2003, 12-2.3.

[3] Athey K., *EVM – Current Solution and Roadmap to Adoption*, QuantumPM, 2007.

[4] Czarnigowska A., *Earned value method as a tool for project control*, Budownictwo i Architektura, 3, 2008, 15-32.

[5] Department of Energy, *EVM TUTORIALS*, USA, 2003 (http://energy.gov/management/office-management/operational-management/project-management/earned-value-management).

[6] Fleming Q., Koppelman J., *Earned value project management*, Newtowns Square. PA: PMI, 2000.

[7] Hernández JIM., Olaso JRO., Gómez JR.; *Technical Performance Based Earned Value as a Management Tool for Engineering Projects*, Chapter 7, 2013, (http://dx.doi.org/10.5772/54497).

[8] Jacob D., *Forecasting project schedule completion with earned value*.

[9] *Metrics*, The Measurable News March:1, 2003, 7-9.

[10] Moslemi L., Shadrokh S., Salehipour A., *A fuzzy approach for the earned value management, International Journal of Project Management*, 29 (6), 2011, 764-772.

[11] Lipke W., *Schedule is different*, The Measurable News 2003 (March), 31-4.

[12] Połoński M., *Prognozowanie czasu zakończenia inwestycji na podstawie jej bieżącego zaawansowania*., Metody ilościowe w badaniach ekonomicznych Tom XIII/3, 2012, 169-179.

[13] Project Management Institute, *A guide to the Project management Body of Knowledge (PMBOK Guide) – fourth edition*, 2008, 181-186.

[14] Sagar K., Bhosekar, Gayatri Vyas, *Cost controlling using Earned Value Analysis in construction Industries*, International Journal if Engineering and Innovative Technology (IJEIT), Vol. 1, Issue 4, April 2012.

[15] Vandevoorde S., Vanhoucke M., *Earned Value Forecast Accuracy and Activity Criticality, Measurable News*, Issue 3, The Summer 2008.

[16] Vandevoorde S., Vanhoucke M., *A comparison of different project duration forecasting methods using earned value metrics*, International Journal of Project Management 24, 2006, 289-302.

[17] Vandevoorde S., Vanhoucke M., *Measuring the Accuracy of Earned Value/Earned Schedule Forecasting Predistors*, The Measurable News, Winter 2007–2008.

[18] Vandevoorde S., Vanhoucke M., *Earned Value Forecast Accuracy and Activity Criticality, Measurable News*, Issue 3, Summer 2008.

[19] Vandevoorde S., Vanhoucke M., *Forecasting a Project's Duration under Various Topological Structures*, Measurable News, Issue 1, The Spring 2009.

[20] Webb A., *Integrated cost and schedule control – a survey of UK experience*, The engineering Journal, t. 5, No. 3, June 1995.

[21] OR-AS, *Protrack* (http://www.or-as.be/).