International Scientific Conference *People, Buildings and Environment 2014* (PBE2014)
15-17 October, 2014, Kroměříž, Czech Republic, www.fce.vutbr.cz/ekr/PBE

KEYNOTE LECTURE

APPLICATION OF NET PRESENT EARNED VALUE METHODOLOGY IN CONSTRUCTION PROJECTS

Aleksander Srdić[1]*, Jana Šelih[1]

[1] Faculty of Civil and Geodetic Engineering, Jamova cesta 2, 1000 Ljubljana, Slovenija

Abstract

Uncertainties are an inevitable part of a construction project and may lead to time and/or cost deviations from the original project plan. Both are highly undesirable from the client's as well as from contracor's side. Therefore, during project execution, project manager wishes to control the risk of not achieving the initial plan. Earned Value Analysis (EVA) is one of the most frequently used methods to carry out his task.

EVA, however, does not account for the time value of money which is important for long-term projects of high value, such as construction projects. To overcome this drawback of EVA, research presented in the paper proposes an efficient approach by which EVA and Net Present Value (NPV) are combined into a single methodology. The proposed methodology uses the Earned Schedule (ES) for the estimation of project duration. The use of the new methodology is demonstrated on a selected case study from construction field. The results show that a relatively simple and efficient tool that can be successfully applied for long term, cost intensive projects, has been developed.

Key words

Earned schedule; earned value analysis; net present value; project control

To cite this paper: *Srdić, A., Šelih, J. (2014). Development of Net Present Earned Value Methodology and its Application in Construction Projects, In conference proceedings of People, Buildings and Environment 2014, an international scientific conference, Kroměříž, Czech Republic, pp. 16-27, ISSN: 1805-6784.*

*Corresponding author: Tel.: +386-1-4768-576; + 386-41-605-275
E-mail address: aleksander.srdic@fgg.uni-lj.si

1 INTRODUCTION

Project execution and its monitoring and control are the longest phases in project life cycle. In this project phase, the occurrence of unforeseen circumstances and changes in the projects scope can often be noticed. This is particularly valid for constructions projects. As a consequence, monitoring of project development starts on construction site, by gathering costs and actual realisation date of activities. Any deviation from the contract-baseline schedule and budgeted costs should be identified and then analysed in order to be able to answer two questions, that are, from client's point of view, the most relevant: When, and at what costs the project will be finished.

The answers are based on the project status at the control date, which is a combination of finished project activities and associated actual costs. Analyses of actual data provide also the baseline for the estimates of future project realisation.

The most established methodology for project monitoring and making decisions on the top project management level is Earned Value Analysis (EVA). This method is measuring project performance and progress from the viewpoint of achieving the scope, schedule and costs, and is integrating these parameters into a single system.

In order to ensure successful project execution, special attention should be placed to the project feasibility phase, where goals of the project are already clearly defined, and risks are evaluated. Two main decision criteria employed in this phase are project Net Present Value, NPV and Internal Rate of Return, IRR. Despite significance of these two indicators, both of them are mainly ignored during construction phase.

It is clear that EVA-based key indicators are not sufficient for efficient project monitoring. The methodology proposed in this paper tries to overcome this deficit. Costs performance index (CPI) conventionally used in EVA for the estimation of the remaining cost, and estimation of the project end, based on schedule performance index (SPI) that is calculated with Earned Schedule (ES) methodology are used. To evaluate the estimated project financial outcome, all realised and estimated remaining costs are time phased to corresponding intervals and discounted to the present value, and project estimate of the net present value can be determined. In addition to the estimate of the profit that is a conventional EVA indicator, project revenues have to be included as an indicator as well.

The purpose of the research presented in this paper is to identify challenges associated with the use of Earned Value Analysis (EVA) in construction projects, and to establish a model by which Net Present Value (NPV) is accounted for within Earned Value Analysis.

2 STATE OF THE ART

Earned Value Analysis is well accepted methodology ever since 1979 when U.S. Department of Energy proposed the Earned Value System as complementary control aid to the classical scheduling methods - i.e., to the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). Aside from the problems associated with poor cost or duration estimates, both methods, CPM and PERT, have strong limitations when trying to describe the variable nature of projects, especially construction projects [1].

From the introduction of EVA onward, researchers are predominantly focused on enhanced reliability of project performance indexes [2], [3], [4]. As a consequence, additional parameters, such as Earned Schedule [5], [6], relationships between factor [7] or implication of different techniques for predicting [8], such as regression [9], Neural Networks [10] and Kalman filter [11] were developed.

Another aspect of research that is currently being undertaken in this area is incorporating project-related uncertainty into EVA as a part of the project risk management. Research endeavours that address this issue are predominantly based on fuzzy approach [12].

Recently, additional project success indicators, e.g. the estimated project NPV during project execution have been proposed [13], to be considered within EVA.

3 METHODOLOGY

3.1 Fundamentals of Earned Value Analysis

EVA is used to measure the performance of a project. It provides a systematic approach to integration and measurement of scope, cost and schedule accomplishments in a project. The most important indicators employed in the analysis are CPI (costs performance index) and SPI (schedule performance index). The efficient use of EVA requires that project WBS (Work Breakdown Structure), CBS (Cost Breakdown Structure) and feasible project schedule with reliable costs estimate are carefully prepared.

Gathering of activities' status and related incurred cost needs to be accurate, therefore significant effort is required to carry out this task. However, after this stage is completed, the analysis is simple and quick.

Key indicators

Project control methodology is based on analysis of time phased project costs (fig.1). The starting point for the analysis and calculation of project performance indicators is project baseline cash flow – BCWS(t) (Budgeted Cost of Work Scheduled), that represents cumulative budgeted cost at given time during project execution.

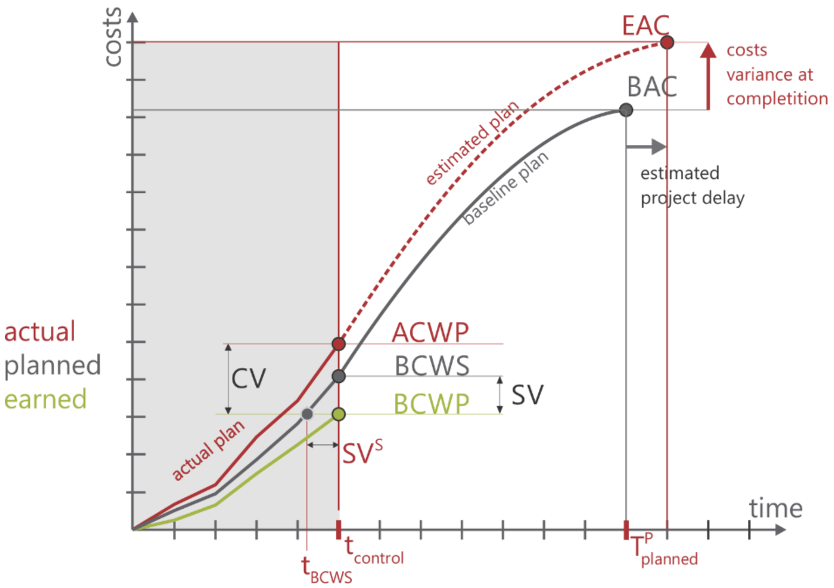


Fig. 1: Basic elements of EVA

EVA provides two key indicators: CV(t) and SV(t) - cost and schedule variance at time of control, t= $t_{control}$. Both indicators describe the calculated difference towards BCWS, therefore they are defined as:

$$CV(t) = ACWP(t) - BCWP(t) \quad (1)$$

$$SV(t) = BCWP(t) - BCWS(t) \tag{2}$$

where:

$ACWP(t)\ldots$ Actual Cost of Work Performed, and

$BCWP(t)\ldots$ Budgeted Cost of Work Performed

Project performance assessment, estimation of time of project completion and cost at completion are assessed by the following performance indexes at a given time t:

- Cost performance index, CPI

$$CPI(t) = \frac{BCWP(t)}{ACWP(t)} \tag{3}$$

When the cost of completing the work is right on plan, CPI equals to 1. CPI < 1 indicates that cost of completing the work complies to the planned value, and CPI >1 indicates that the cost is smaller than planned.

- Schedule performance index, SPI

$$SPI(t) = \frac{BCWP(t)}{BCWS(t)} \tag{4}$$

When the project is on schedule, SPI equals to 1. SPI < 1 indicates that the project is behind the schedule, and SPI >1 indicates that the project is ahead of the schedule.

3.2 Earned Schedule

Expression of Schedule Variance (eq.2), where time performance is based on cost ratio, seems to be somehow strange, because time and cost aren't same categories. Many authors ([2], [3], [4], [5], [6]) recommend use of Earned Schedule approach to determine SV and SPI, which are based on time of control ($t_{control}$) and time of when BCWS=BCWP (t_{BCWS}) (fig. 1).

$$SV^S(t_{control}) = t_{control} - t_{BCWS} \tag{5}$$

$$SPI^S(t_{control}) = \frac{t_{BCWS}}{t_{control}} \tag{6}$$

where:

$SV^S\ldots$ schedule variance based on Earned Schedule method

$SPI^S\ldots$ schedule performance index based on Earned Schedule method

3.3 Net Present Value (NPV)

In project management, the time and money are different categories interconnected by the interest rate. Net present value (NPV) is the sum of time phased costs and revenues discounted to the present value, over the time period under consideration (eq. 7):

$$NPV = \sum_{t=0}^{T_P} \frac{C_t}{(1+r)^t} \tag{7}$$

where:

$t\ldots$ time period counted from time of present value

$C_t\ldots$ cost or revenue in period t

$r\ldots$ discount rate for the considered time interval

3.4 Merging NPV into EVA

Basic EVA does not take into account the time value of money. Consequently, in long term construction projects, where delays with duration of several months can occur, the methodology does not exhibit proper cost performance index. Even if actual cost doesn't overcome the budgeted value, it does not mean that the project will be finished with planned profit when time value of money is taken into the account.

In addition, EVA has a systematic failure: at the end of project, earned costs are the same as budgeted. This means that despite the eventual delay, SPI at the end is always 1, and does not show the discrepancies from the original plan that occur during execution.

The method proposed in this work tries to overcome the above presented lack of crucial information by comparing present actual and earned value with budgeted present value.

Early and late project schedule

Before time value of cost and revenue is taken into account, different possible timing of activities' realisation should be clarified. Usually, project baseline schedule is based on early dates of activities' realisation. The main reason for this decision stems from the desire to schedule activities with maximum possible float time, so that eventual delays that may occur during project execution can be compensated.

Insight into available float can be indirectly presented with early $BCWS^E$ and late $BCWS^L$ cumulative diagram, presented in Fig. 2a.

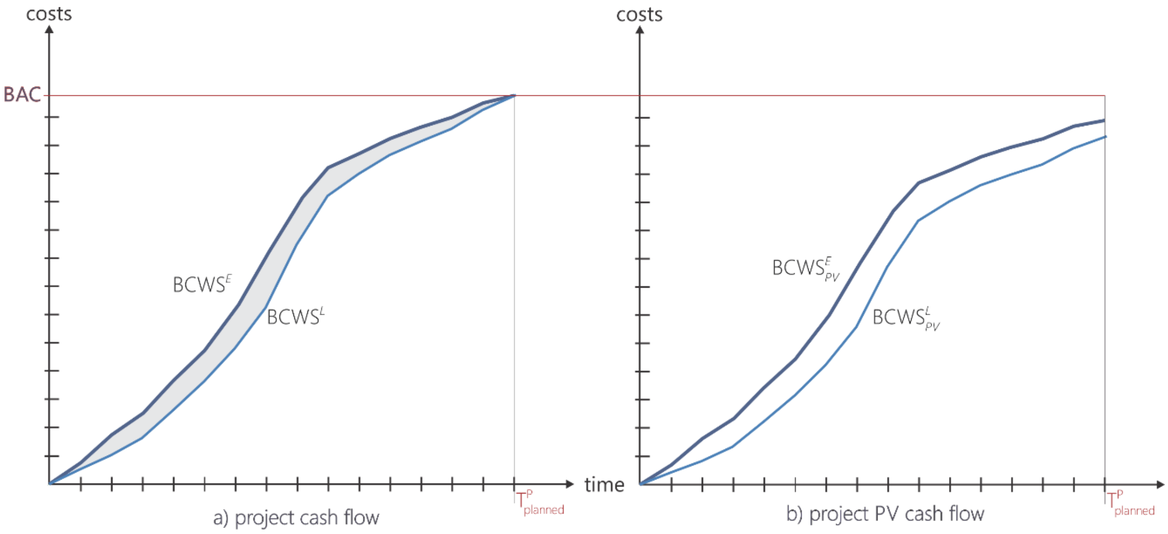


Fig. 2: Cumulative budgeted cost at project activities early and late realisation

If we take into the account that delayed occurrence of the selected cost means greater value discount, PV value of cost for activities realisation at late time - $BCWS_{PV}^{L}$ are lower than PV of early time - $BCWS_{PV}^{E}$ (fig. 2b). A conflict situation regarding the activities and project time reserve (float) appears. Real world project management is compromise, so PV of budgeted cost work performed, $BCWP_{PV}$, should be compared with both - late and early budgeted present value (eq. 8, 9).

$$SPI(t)^{E} = \frac{BCWP(t)_{PV}}{BCWS(t)_{PV}^{E}} \tag{8}$$

$$SPI(t)^L = \frac{BCWP(t)_{PV}}{BCWS(t)^L_{PV}} \tag{9}$$

The meaning of the performance indexes defined by eqs.(8) and (9) is presented in Table 1.

Tab. 1: project time performance

Indexes Value	Meaning
$SPI^E > 1$	ahead of schedule
$SPI^E < 1$ and $SPI^L > 1$	still on schedule, float decreased
$SPI^L < 1$	behind schedule

Cost performance index

Cost performance index, CPI, can be calculated in the same manner as in existing EVA (eq. 3). However, even if $CPI < 1$, it is possible that $CPI_{PV} > 1$. If, at the same time, the relations $SPI^E < 1$, and $SPI^L > 1$ apply for these two performance indexes, it means that the project will be finished with expected NPV.

Estimate at completion

During project execution, there are another two very important questions for the project manager: when will the project be finished and at what costs and profit? Simple comparison of costs and revenues does not show the real project success. If revenues occur at the end of project (e.g. build and sell apartments on the market), only the project's NPV is relevant for its success evaluation. In such case, despite the fact that late accruing of costs decreases their present value, the present value of revenues is also greatly decreased due to the project delay. Estimate of project duration is therefore a crucial parameter in the calculation of NPV, by which project profit can be estimated.

Within EVA, project duration estimate is based on SPI and original (baseline) duration. The following equation applies:

$$ED = \frac{OD}{SPI} \tag{10}$$

where: ED and OD are estimated, and original duration, respectively.

This estimate is often inappropriate for the construction project, due to the fact that major delays frequently appear during the first third of the project. Typical activities where delays can occur in this part of the project are, for example, establishing contractors' coordination, or dealing with unforeseen geotechnical conditions. These delays cannot be spread linearly over the whole project duration, therefore SPI is not a suitable indicator for assessing the construction project performance.

SPI also does not exhibit realistic performance during the last third of project execution, due to the systematic failure of EVA already mentioned. Therefore, the present research proposes an improved methodology that is based on Earned Schedule methodology. The estimates of project finish and the remaining duration of the project are formulated as:

- simply adding current delay SV^S to the original project duration $T^P_{planned}$, to obtain the estimated duration, ED^+

$$ED^+ = T^P_{planned} + SV^S \tag{11}$$

- determination of project duration based on Earned Schedule method's SPI:
  - $SPI^{S,L}$ - according to late dates ($BCWS^{L}$)

$$ED^{xL} = \frac{T^{P}_{planned}}{SPI^{S,L}} \tag{12}$$

  - $SPI^{S,E}$ - according to early dates ($BCWS^{E}$)

$$ED^{xE} = \frac{T^{P}_{planned}}{SPI^{S,E}} \tag{13}$$

Estimate of remaining costs - ETC (Estimate to Complete) flow

When time value of future costs is considered, it is necessary to determine the cost flow until the end of project. Estimation of the remaining cost (ETC) is calculated as the difference between total budgeted costs and budgeted cost of work performed, corrected with current cost performance index

$$ETC = \frac{(BAC - BCWP)}{CPI} \tag{12}$$

The remaining costs are spread on time interval between time of control and estimated duration, as schematically presented in Fig. 3.

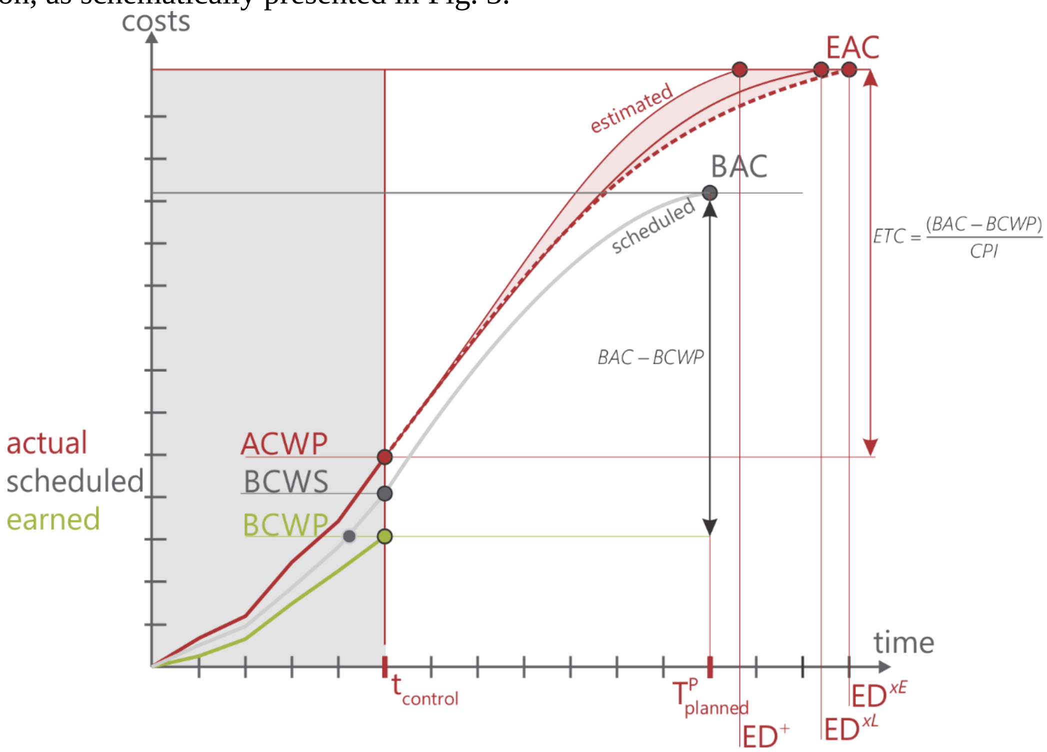


Fig. 3: Cumulative curve of actual and estimated remaining costs

Present Value of combined ACWP and ETC

Based on combination of actual and estimated to completion costs flow (Fig.3), their present value can be determined by the Eq.(7) and use of different estimated duration (ED^{+} , ED^{xL} , ED^{xE}). Present values, PV, of 3 different scenarios are labelled as EAC^{+}_{PV} , EAC^{xL}_{PV} and EAC^{xE}_{PV} .

Estimated Project NPV at completion

By adding time phased revenues based to project estimated completion, the proposed methodology provides 5 different project net present values:

- P_{NPV}^{BE} … project early baseline NPV
- P_{NPV}^{BE} … project late baseline NPV
- P_{NPV}^{+} … project $EAC_{PV}^{+} + R_{PV}^{+}$
- P_{NPV}^{xE} … project $EAC_{PV}^{xE} + R_{PV}^{xE}$
- P_{NPV}^{xL} … project $EAC_{PV}^{xL} + R_{PV}^{xL}$

4 CASE STUDY

The practical use of proposed methodology is presented for the following case study -residential building project.

4.1 Baseline data (Fig. 4)

Costs and revenues are presented as ‰ of the total costs. The selected annual discount rate is 8%.

The following data were provided:

OD= 30 month

BAC= 1.000,0 unit

R=1.200 unit at the end of project; Profit= 200 unit

4.2 Expected NPV of project

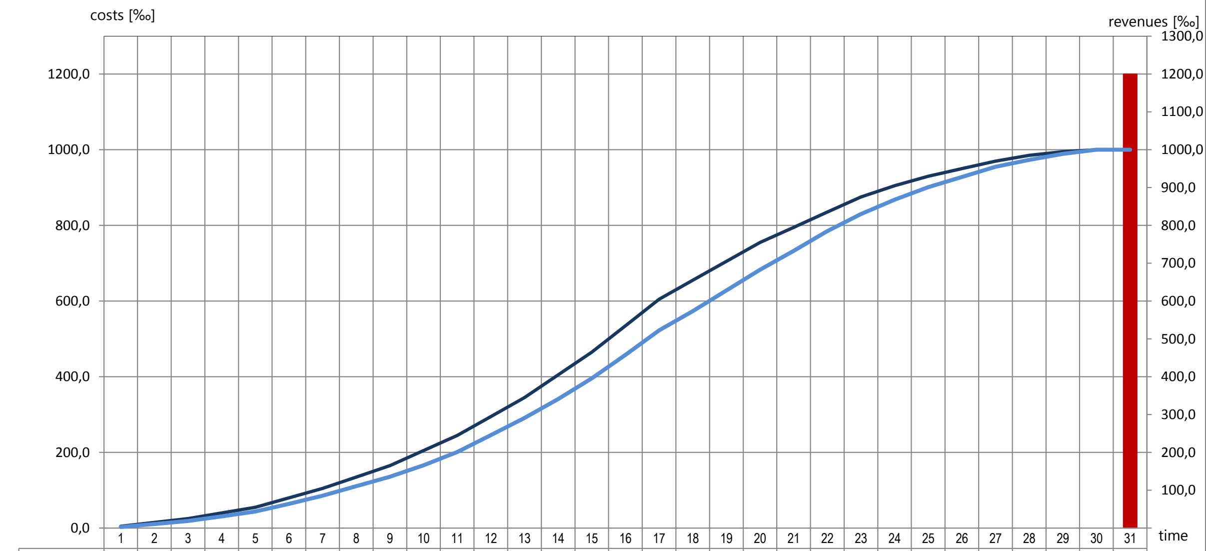
Net present values were determined for the options “Early schedule” and “Late schedule”.
The following values are obtained:

- Early schedule : $BAC_{PV}^{E} = 903,7$ $R_{PV} = 983,6$ $P_{NPV}^{E} = 983,6 - 903,7 = 79,9$
- Late schedule : $BAC_{PV}^{L} = 897,3$ $R_{PV} = 983,6$ $P_{NPV}^{L} = 983,6 - 897,3 = 86,3$

4.3 Project schedule performance control

Project performance is evaluated from the viewpoint of cumulative costs development with time. The control point is set at $T_{control}=15^{th}$ month.

Fig. 5 presents the costs flow from project start to control time. Comparison of BCWP with $BCWS^{E}$ shows that it should be earned at 13,6 month from the start, which means that the value of SV is -1,4 month, according to the Earned Schedule method. SV based on comparing with $BCWS^{L}$ is less critical, only 0,3 months.



time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
R	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
BCWS E	5,0	15,0	25,0	40,0	55,0	80,0	105,0	135,0	165,0	205,0	245,0	295,0	345,0	405,0	465,0	535,0
BCWS L	3,0	11,0	19,0	31,0	44,0	64,0	86,0	111,0	136,0	166,0	201,0	246,0	291,0	341,0	396,0	458,0

time	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
R	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1200,
BCWS E	605,0	655,0	705,0	755,0	795,0	835,0	875,0	905,0	930,0	950,0	970,0	985,0	995,0	1000,	1000,
BCWS L	523,0	573,0	628,0	683,0	733,0	785,0	830,0	868,0	901,0	928,0	955,0	973,0	989,0	1000,	1000,

Fig. 4: Cumulative costs at early/late time and revenue at the end of project

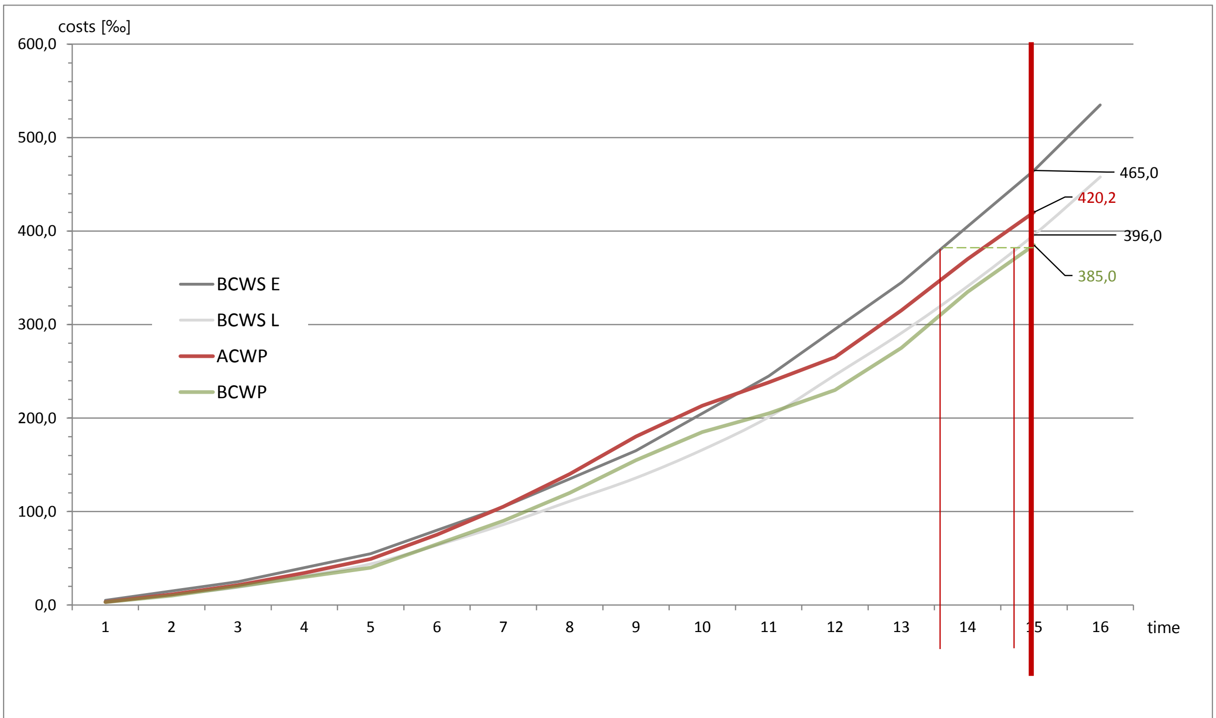


Fig. 5: Cumulative costs at control time

Project performance is assessed by several indexes, as presented in Table 2 and figure 5. Results of the analysis show that at the time of the assessment, the actual costs are exceeding the planned ones, but estimated costs are lower than revenue and profit is still expected. Further, all obtained values for the indicators *SPI, ED,* SV^S, SPI^S *and* ED^S indicate that the project is behind the schedule. According to EVA, expected delay is about 6 months while Earned Schedule SPI^S shows that the estimated delay is only 3 months when compared to early schedule and almost no delay (0,6 month) when compared to the late schedule. Considering the fact that the control time is in halfway of project duration and approximate half of float is already consumed, the estimated project delay is about 4,5 months.

In order to cope efficiently with uncertainty, several different scenarios (different EAC and ED) need to be produced. Only then, a better insight into possible NPV (Fig. 6) can be gained.

Tab. 2: project performance indicators

Indicators	**Value**	**Meaning**
Earned Value Analysis		
CPI	0,916	Costs overrun
SPI	0,828	Behind schedule
EAC	1.091,4	1.200 – 1.091,4=108,6 (Profit decrease)
ED	36 mo	Estimated project delay 6 mo.
Earned Schedule		
SV^S	1,4 mo	Current delay 1,4 mo
SPI^S	0,91	Behind schedule
ED^S	33,09 mo	Estimated project delay 3 mo.
Proposed methodology (EVA+ES+NPV)		
SV^{SE}	1,4 mo	Current delay 1,4 mo behind early schedule
SV^{SL}	0,3 mo	Current delay 0,3 mo behind late schedule
SPI^{SE}	0,91	SPI based on ES early - delay
SPI^{SL}	0,98	SPI based on ES early-small delay
ED^+	30,85 mo	Estimated project delay 1 mo.
ED^{xE}	33,09 mo	Estimated project delay 3 mo.
ED^{xE}	30,61 mo	Estimated project delay 0,5 mo.
P^+_{NPV}	-2,3	Negative project NPV – no profit
P^{xE}_{NPV}	-13,1	Negative project NPV – loss
P^{xL}_{NPV}	-1,1	Negative project NPV – no profit

5 DISCUSSION

The results obtained by using the combined Earned Value Method and Net Present Value concept show that in large long lasting projects, the use of this method is justified. Cumulative costs presented in Fig.4 show that significant differences may occur during project execution. This may not necessarily mean that the project is at risk of exceeding the deadline, or the contractual cost. Nevertheless, it can affect the cash flow at a given moment. As a consequence, it is clear that EVA must be supplemented by NPV, especially when project are cost- and time-consuming.

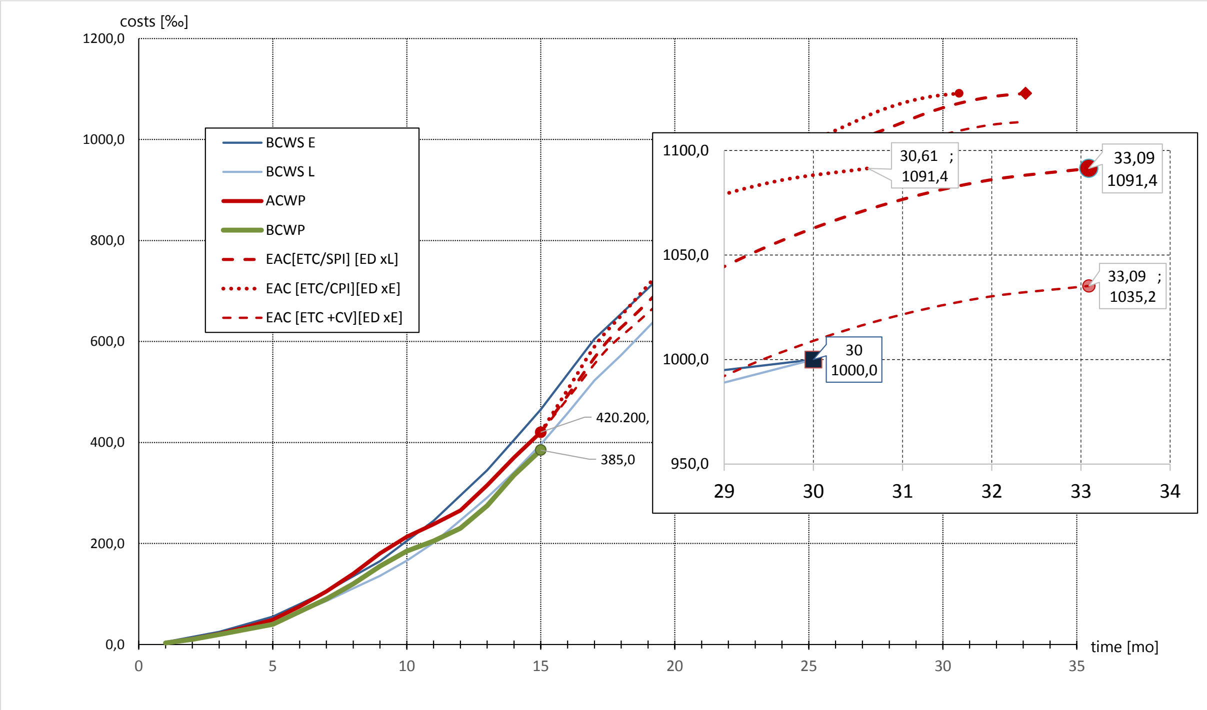


Fig. 6: Cumulative expected costs, based on project performance at control time

Tab. 3: Project NPV with respect to different discount rates and project performance indexes

NPV	ΔTp		Discount rate		
	[month]	[%]	8%	7%	6%
P^{+}_{NPV}	+0,85	2,83	-2,3	9,5	21,8
P^{xE}_{NPV}	+3,09	10,29	-13,1	-0,3	13,2
P^{xL}_{NPV}	0,61	2,04	-1,1	10,6	22,7

Fig.5, where cumulative results at control time are presented for different alternatives, shows that discrepancies can be crucial for the analysis of past results, as well as for the prediction of future trends. Values for project performance indicators collected in Table 3 show that for the time considered, the project is behind schedule and that it exhibits a cost overrun. This observation should not, as already discussed, be taken as the final outcome; the project needs to be completed in order to make the final evaluation. Finally, it should be noted that the calculated NPV depends upon the assumed discount rate, and upon the time-to-completion index value.

6 CONCLUSION

Large, cost and time consuming construction projects require specific approaches in all project phases. Often, significant attention is placed to the planning stage, but execution and control stage are neglected due to time pressures that often arise in the construction stage.

The proposed Net Present Earned Value Methodology can facilitate control that needs to be applied during execution. When it is used, special attention should be paid to the time intervals for which it has been shown that the suitability of the proposed method is low, i.e. first and last third of the total project time. However, when these specific topics are adequately addressed, the methodology can be extremely useful for overall project control.

REFERENCES

[1] Barraza G., Back W., Mata F. (2000). Probabilistic monitoring of project performance using SS-curves. *J. Constr. Eng.*, April, pp. 142–148.

[2] Lipke W. (2012). Speculations on Project Duration Forecasting. *PM World Today*, **14**(3).

[3] Czarnigowska A., Jaskowski P., Biruk S. (2011). Project performance reporting and prediction: extensions of earned value management. *Int. J. Bus. Manag. Stud.*, **3**(1), pp. 11–20.

[4] Lipke W. (2014). Examining Project Duration Forecasting Reliability. *PM World J.*, 3(3), pp. 1–10, 2014.

[5] Görög M. (2009). A comprehensive model for planning and controlling contractor cash-flow. *Int. J. Proj. Manag.*, 27(5)5, pp. 481–492.

[6] Vandevoorde S., Vanhoucke M. (2006). A comparison of different project duration forecasting methods using earned value metrics. *Int. J. Proj. Manag.*, 24(4), pp. 289–302.

[7] Cheng M. Y., Huang C. C.,Van Roy A. F. (2013). Predicting Project Success in Construction using an Evolutionary Gaussian Process Inference Model. *J. Civ. Eng. Manag.*, **19**(1), pp. 202–211.

[8] Roodposhti F. R., Pakmaram A., Alamdari B. K. (2012). Forecasting Final Schedule and Cost of Projects by Using Statistical and Mathematical Method. *Int. J. Appl. Oper. Res.*, **1**(3), pp. 105–115.

[9] Narbaev T., De Marco A. (2014). An Earned Schedule-based regression model to improve cost estimate at completion. *Int. J. Proj. Manag.*

[10] Iranmanesh S., Zarezadeh M. (2008). Application of Artificial Neural Network to Forecast Actual Cost of a Project to Improve Earned Value Management System. *Proceeding World Acad. Sci.* August, **32**, pp. 240–244.

[11] Kim B. C., Kim H. (2014). Sensitivity of Earned Value Schedule Forecasting to S-Curve Patterns. *J. Constr. Eng. Manag.*, p. 04014023.

[12] Moslemi Naeni L., Shadrokh S., SalehipourA. (2014). A fuzzy approach for the earned value management. *Int. J. Proj. Manag.*, **32(**4), pp. 709–716.

[13] Jordanger B. I., Klakegg O. J. (2013). Value Management Beyond Earned Value. *PM World J.*, **2**(2), pp. 12.