CONSTRUCTION PROJECT RISK CONTROL BASED ON EXPERTISE USING FUZZY SET THEORY

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ABSTRACT: The article shows procedure, which enables to control risk during project lifetime on the basis of earned value theory ratings variation in feasibility study. Sample project has been divided into typical investment tasks, then schedule and cost estimate have been worked out. Information according possible cost and time variation for any task has been based on expert knowledge, using mathematical instrument, which is fuzzy set theory. Schedules which contain initial data and variations defined by experts have been worked out, using MS-Excel and MS-Project programs. As a result, we get hypothetical graphs showing: Budget Cost of Work Scheduled, optimistic / pessimistic Actual Cost of Work Performed - ACWPopt / ACWPpes, optimistic / pessimistic Budget Cost of Work Performed - BCWPopt / BCWPpes.
In this way, investor or contractor is able to determine at any stage of project, if extreme values haven't been exceeded. It is also possible to specify cost and time risk at feasibility study stage. According to this, project financing is easier to planned, and also less subject to additional problems related with cash flow deadlines.
Presented analysis can be used to control project management at the same time. In case of exceeding extreme values of earned value method ratings, board of directors have knowledge about project management quality.

***Keywords**: Risk, Management, Civil Engineering, Fuzzy Sets, Earned Value Theory, Control*

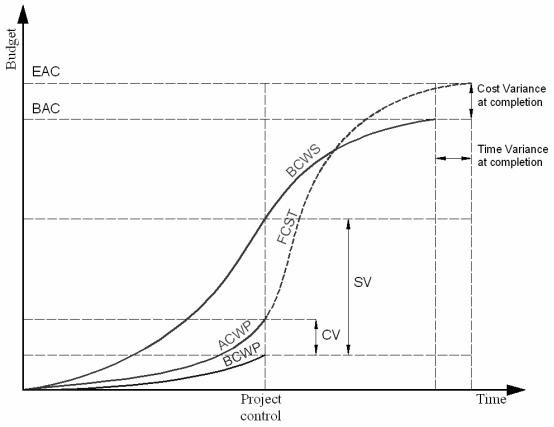
1. INTRODUCTION

The study presented discusses a method enabling control of risk associated with a given investment on the basis of a cost and time schedule, using components of the Earned Value method.

The Earned Value method is based on three main indicators:

- BCWS (Budget Cost of Work Scheduled)
- ACWP (Actual Cost of Work Performed)
- BCWP (Budget Cost of Work Performed)

The BCWS curve is determined during the project planning phase, while the ACWP and BCWP curves are established on the basis of data obtained during the project life cycle. Therefore, ACWP and BCWP curves may be determined only until the current project date. Presented below is a graphic interpretation of these indicators.



BAC – Budget at Completion,
EAC – Estimated at Completion

Fig. 1. A diagram of ACWP, BCWP, BCWS curves – distribution of the project costs in the time function.

According to Fig. 1., the accumulated time and cost schedule curve is the so-called default value of BCWS (green). This curve presents the image of the scheduled project budget in the scheduled time. The ACWP curve is

the actual project cost. It presents the actual expenditures borne for the project. Data for determination of this curve can be obtained from the register of financial documents of the project. The traditional cost deviation is calculated as the difference BCWS-ACWP. This indicator may not tell us the truth about the project condition. Only the third curve – BCWP stands for the difference in relation to the traditional cost deviation measurement. BCWP specifies the planned value of the work performed, which is the project earned value. BCWP informs us of the scheduled cost of the works actually performed.

Project control should thus be organized so that during analysis of budget variances, schedule variances are also taken into account. If the project is being realized more slowly than planned and at the same time it is more costly, the cost parameters of the project may indicate that the project is being implemented appropriately. In order to eliminate such errors, the BCWP curve, or the earned value curve, has been implemented in analysis. Thanks to analysis based on three curves, the following indicators can be obtained:

- Cost Variance: CV = BCWP - ACWP
- Schedule Variance: SV = BCWP - BCWS
- Schedule Performance Index: SPI = BCWP / BCWS
- Cost Performance Index: CPI = BCWP / ACWP

The objective of the work presented was to develop the project control, discussed above, during its implementation, by introducing in analysis threshold values of the main indicators of the earned value method. These values were determined on the basis of expert opinions, using the fuzzy set theory.

The mode of application of the above mathematical apparatus has been presented in a separate study entitled "The time-cost analysis of the construction project planned, taking into account the risk based on expert knowledge using fuzzy sets" It is based on presentation of information obtained from experts in form of a fuzzy set and then its transformation to a format enabling its use in project control during realization. Therefore, the so-called fuzzy modeling has been implemented, which consists of the operation of fuzzification, inference and defuzzification.

2. DESCRIPTION OF THE METHOD

In order to illustrate the algorithm of operation of the method presented, an exemplary investment project has been used, consisting of construction of a residential building. Presented below is the preliminary time schedule, in form of a Gantt chart, and the general cost estimate of construction works. Both the schedule and the cost estimate have been divided into tasks, which specifying the main groups of construction works.

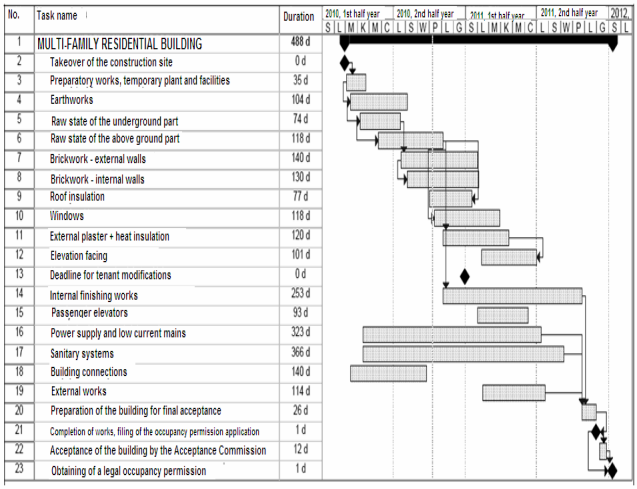


Fig. 2 A Gantt chart for the undertaking planned – a time schedule.

Tab. 1. A tabular breakdown of costs for individual work groups in the investment project.

Id	Name	Costs
MULTI-FAMILY RESIDENTIAL BUILDING		28 346 000
1	Preparatory works, temporary facilities	450 000
2	Earthworks	1 640 000
3	Raw state of the underground part	2 250 000
4	Raw state of the above ground part	5 300 000
5	Brickwork – external works	950 000
6	Brickwork – internal works	825 000
7	Roof insulation	1 320 000
8	Windows	3 120 000
9	External plaster + heat insulation	1 950 000
10	Elevation facing	823 000
11	Internal finishing works	4 220 000
12	Passenger elevators	758 000
13	Power supply and low current installations	1 800 000
14	Sanitary systems	1 350 000
15	Building connections	260 000

16	External works	1 150 000
17	Preparation for final acceptance	180 000

A breakdown of cash flows in the time axis results in a chart of financial flows, that is, a time-cost schedule. In order to prepare such schedule, MS-Project and MS-Excel software has been used. These have been presented below for the investment project under concern as absolute monthly flows, and in the accumulated curve format.

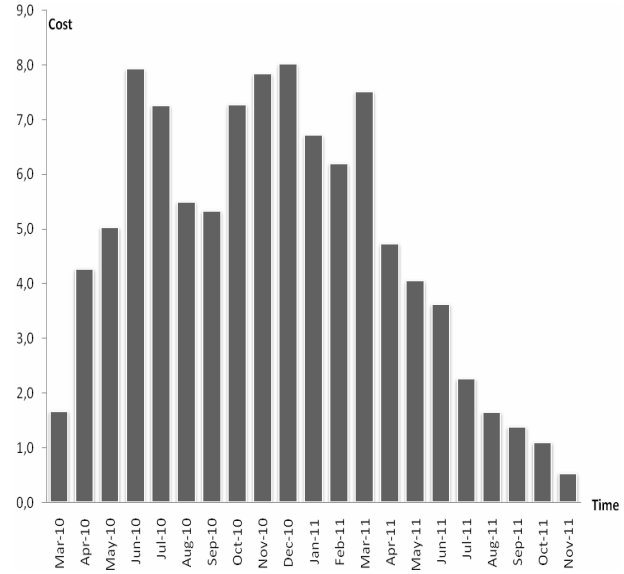


Fig. 3 Time-cost schedule of the planned project

In order to present the cost flow calculated since the project commencement, the so-called accumulated time-cost schedule is used. This has been presented in Fig. 4.

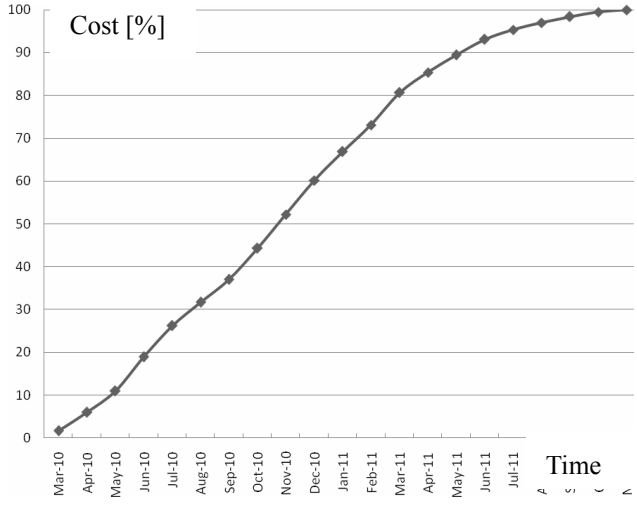


Fig. 4. The accumulated time and cost schedule for the undertaking planned.

The analysis presented allows us to determine clearly whether any of the main indicators of the Earned Value method has been exceeded and whether its value exceeds the threshold values, assumed prior to the project commencement, which are acceptable. The table below presents the threshold values of the time of implementation and cost for individual project tasks. As it has been mentioned earlier, this data was obtained using fuzzy modeling of information received from experts. On its basis, new time and cost schedules are determined for the undertaking, which will serve as a basis for determination of threshold values of indicators of the earned value method.

Tab.2. A breakdown of threshold values of cost and time of individual tasks.

Id.	Description	Rec. time	Opt time	Opt prob.	Pes time	Pes prob.
	Project	**488**	**415**	**0,52**	**539**	**0,47**
1	Preparatory works	35	29	0,57	39	0,48
2	Earthworks	104	96	0,65	130	0,54
3	Raw state - underground	74	59	0,75	83	0,53
4	Envelope	118	86	0,47	124	0,23
5	Brickwork – external works	140	115	0,27	161	0,46
6	Brickwork – internal works	130	104	0,48	75	0,51
7	Roof insulation	77	58	0,44	75	0,51
8	Windows	118	91	0,52	127	0,48
9	External plaster	120	81	0,67	117	0,56
10	Elevation facing	101	83	0,58	116	0,43
11	Internal finishing works	253	215	0,63	291	0,62
12	Passenger elevators	93	70	0,54	102	0,34
13	Power supply	323	234	0,46	323	0,38
14	Sanitary systems	366	302	0,29	421	0,48
15	Building connections	140	119	0,50	158	0,52
16	External works	114	97	0,51	120	0,39
17	Final acceptance	26	23	0,50	33	0,48

Id.	Recom cost	Opt cost	Opt Prob.	Pes cost	Pes prob.
	28 346 000	**22 648 750**	**0,53**	**31 438 350**	**0,46**
1	450 000	360 000	0,69	517 500	0,50
2	1 640 000	1 394 000	0,57	1 886 000	0,41
3	2 250 000	1 631 250	0,53	2 081 250	0,40
4	5 300 000	3 975 000	0,60	5 565 000	0,54
5	950 000	950 000	0,30	1 163 750	0,41
6	825 000	701 250	0,52	1 419 000	0,29
7	1 320 000	990 000	0,45	1 419 000	0,29
8	3 120 000	2 496 000	0,52	3 432 000	0,47
9	1 950 000	1 706 250	0,54	2 242 500	0,75

10	823 000	658 400	0,52	946 450	0,43
11	4 220 000	3 376 000	0,45	4 642 000	0,44
12	758 000	625 350	0,50	890 650	0,33
13	1 800 000	1 485 000	0,77	1 845 000	0,42
14	1 350 000	1 012 500	0,55	1 586 250	0,48
15	260 000	195 000	0,67	286 000	0,51
16	1 150 000	948 750	0,47	1 322 500	0,48
17	180 000	144 000	0,37	193 500	0,46

On the basis of data gathered, it is possible to present the time and cost schedules for threshold values. In the first place, an optimistic and pessimistic BCWP curve has been prepared. For this purpose, the assumed cost values have been applied, while for task times, extreme values determined by experts have been applied. The curves are presented in figure 6.

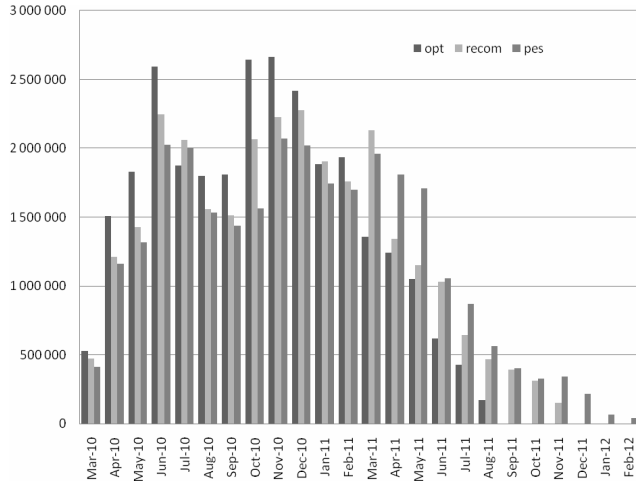


Fig. 5. A time and cost schedule for the investment p roject planned, taking into account the possible time v ariances.

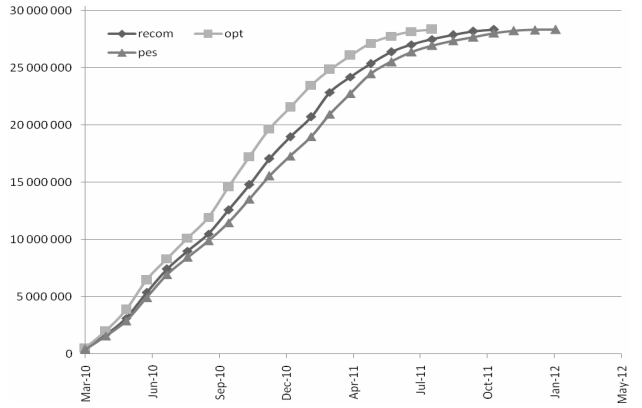


Fig. 6. An accumulated time-cost schedule for the investment planned, taking into account the potential time variances.

The threshold curves for the ACWP chart (actual cost of work performed) have been determined as a result using the values determined by experts both for the time of implementation and the task cost; that is, one curve represents the pessimistic time and cost values, while the other represents the optimistic time and cost values.

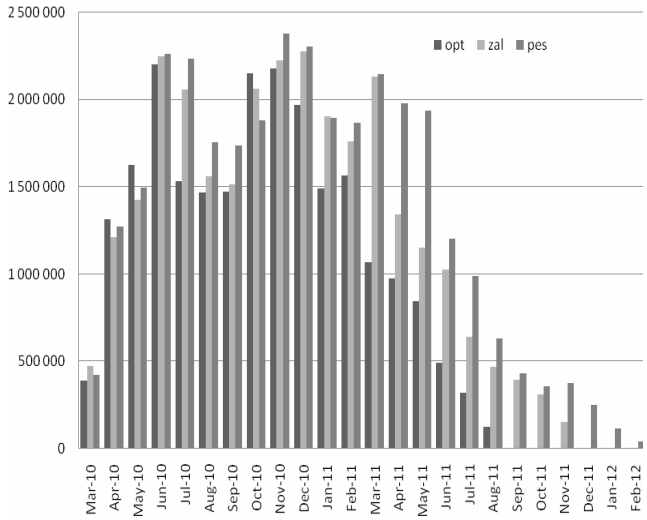


Fig. 7. A time and cost schedule for the investment project planned, taking into account the possible cost and time variances.

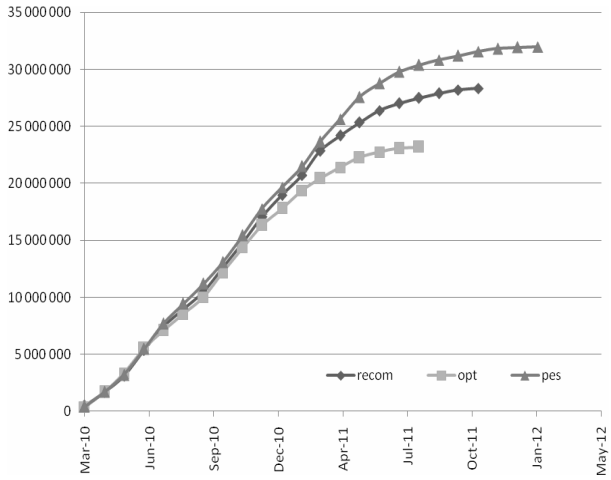


Fig. 8. An accumulated time and cost schedule for the investment project planned, taking into account the possible cost and time variances.

Using the above curves, that is, the pessimistic version of BCWP, the optimistic version of BCWP (cf Fig. 6) and the pessimistic version of ACWP, the optimistic version of

ACWP (cf Fig. 8), threshold values of the earned value method indicators were established.

• Cost Variance: CV=BCWP - ACWP
• Schedule Variance: SV=BCWP - BCWS
• Schedule Performance Index: SPI=BCWP/BCWS
• Cost Performance Index: CPI=BCWP/ACWP

The CPI indicator shows the part of costs borne in accordance with the budget planned. CPI = 0.85 means that out of every zloty spent, only 0.85 PLN has been spent in accordance with the budget, while 0.15 PLN is an expense that was not included in the scheduled cost of the undertaking. If CPI or SPI is less than one, it means that the project is being implemented at an excessive cost (CPI<1) or it is delayed (SPI<1)

Moreover, the earned value method allows for calculation of percentage performance indicators, such as:
• Percent Complete Scheduled: PCS=BCWS/BAC
• Percent Complete: PC=BCWP/BAC
• Percent Complete Actual: PCA = ACWP/BAC

On the basis of the earned value method, it is possible to make budget forecasts during implementation. Such forecasting is based on the following indicators:
• The required cost performance indicator: CPI = (BAC–BCWP)/(BAC–ACWP)
• The estimated cost at completion, assuming that the tendency is maintained (Estimated At Completion): EAC = BAC/CPI,
• The estimated cost at completion, assuming that further costs are borne according to budget (Estimated At Completion): EAC = ACWP + (BAC–BCWP)
• Budget Variance At Completion: VAC = BAC–EAC

On the basis of the above formulas, values of the key coefficients of the earned value method have been obtained, that is, CV, SV, CPI, SPI. On the basis of values specified for a defined deadline, average values have been determined. The results have been presented in the table below.

Tab. 3. A tabular breakdown of threshold values of indicators of the Earned Value method

Date ->	10-04-01	10-10-01	11-04-01	11-10-01	Ave-rage
BCWS	1 685 689	12 559 499	24 199 155	28 193 692	
BCWPopt	2 035 919	14 580 853	26 078 327	28 346 000	
BCWPpes	1 575 353	11 454 953	22 760 093	27 683 269	
ACWPopt	1 704 009	12 160 486	21 413 978	23 195 150	
ACWPpes	1 696 414	13 066 212	25 642 600	31 198 166	
CVopt= BCWPopt - ACWPopt	331 910	2 420 367	4 664 348	5 150 850	
CVpes= BCWPpes - ACWPpes	-121 062	-1 611 259	-2 882 507	-3 514 897	
SVopt= BCWPopt - BCWS	350 230	2 021 354	1 879 172	152 308	
SVpes= BCWPpes - BCWS	-110 337	-1 104 546	-1 439 062	-510 423	
CPIopt= BCWPopt/ACWPopt	1,19	1,20	1,22	1,22	**1,21**
CPIpes= BCWPpes/ACWPpes	0,93	0,88	0,89	0,89	**0,89**
SPIopt= BCWPopt/BCWS	1,21	1,16	1,08	1,01	**1,10**
SPIpes= BCWPpes/BCWS	0,93	0,91	0,94	0,98	**0,94**

3. CONCLUSION

Thanks to time and cost analysis, at the level of individual tasks, it was possible to determine cash flows in the time function for different variants, obtaining 5 possible curves, that is, BCWS, BCWPopt, BCWPpes, ACWPopt, ACWPpes. In this way, at any time during the project life cycle, the investor or the general contractor is able to determine whether the threshold values of the earned value method indicators have not been exceeded. At the same time, at the stage preceding decision-making, the investor is able to determine the possible risk (variance) of the assumed implementation cost or time.

Having the knowledge on the time and cost variances so far, the general contractor will find it easier to plan the financing of the project, without exposing the project to

additional problems, associated with delayed payments.

The time and cost analysis presented may at the same time be applied to control of the undertaking by the project team. In the case of exceeding of CPI or SPI pessimistic values during the project implementation, the management board is able to determine clearly the quality of actions of the project managers.