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# The time-cost analysis of schedule monitoring using the earned value method

# Analiza czasowo-kosztowa w monitoringu harmonogramu metodą wartości uzyskanej

**Abstract**

Maintaining the financial liquidity of construction companies during the implementation of large investment contracts is one of the main budgetary problems when planning their schedules. Despite the unquestioned, greater than ever, development of effective methods of planning, coordinating and controlling, the increase in the complexity of the organization's operating conditions makes it no easier to succeed in project management. This article attempts to analyse the impact of unplanned time and cost deviations on the liquidity of a construction project. Deviations from the planned costs and expenses incurred by the contractor were used as an example in this study.

**Keywords:** Earned value method, time-cost deviation, schedule

**Streszczenie**

Utrzymanie płynności finansowej przedsiębiorstw budowlanych przy realizacji dużych kontraktów inwestycyjnych jest jednym z podstawowych problemów budżetowych przy planowaniu ich harmonogramów. Mimo niekwestionowanego, znaczniejszego niż kiedykolwiek rozwoju skutecznych metod planowania, koordynowania i kontrolowania, wzrost komplikacji warunków funkcjonowania organizacji powoduje, że osiągnięcie sukcesu w zarządzaniu projektami nie jest łatwiejsze. W artykule podjęto próbę analizy wpływu nieplanowanych odchyleń czasowych i kosztowych na płynność finansową przedsięwzięcia budowlanego. W badaniu odchyleń kosztów planowanych i kosztów poniesionych przez wykonawcę posłużono się przykładem zrealizowanej inwestycji.

**Słowa kluczowe:** Metoda wartości uzyskanej, odchylenia czasowo-kosztowe, harmonogram

## 1. Introduction

The implementation of construction projects is a specific and particularly difficult economic activity [3]. Exceeding of the assumed production costs, which is very often seen in the practice, causes that it is necessary to carry out research of the envisaged implementation conditions and chances of possible savings related to them.

Searching for the possible investment scenario which is favourable for the contractor in terms of the works costs is a very complex issue. In practice, the problem is solved by using a simplified cost calculation which takes into account only costs as determined by cost analysis. They are intended to assess the organizational solutions, but not to assess the financial performance of the company [1]. Maintaining the liquidity of construction companies during the implementation of large investments is one of the main budgetary problems when planning the work schedules of construction projects [4].

Assessment of the tasks implementation by analysing deviations gives, in the case of cost accounting standards, a lot of useful information, such as variations in the quantity and value of the cross section of the calculation position (e.g. quantitative variation of direct materials, direct wage rates deviation) [3].

The selection of methods of production control depends upon many factors, especially: the degree of reproducibility of production, how detailed the available data is, how detailed the kept records are, use of planning and cadastral documentation, degree of use of computer techniques and the organisational culture prevailing in the company [6].

The earned value method (EVM) is considered to be an advanced control method for the projects which provides calculation results in the form of both quantitative and qualitative indicators [5].

EVM involves the control of the project by comparing executed scope of works along with their actual completion dates and the actual costs incurred with the adopted schedule and the project budget [6].

Compared with the traditional method of controlling progress of a construction project, EVM takes into account, apart from the planned and incurred costs, the so-called third dimension, i.e. the earned value which represents the planned value of the actually executed scope of works [2].

The basis of the earned value method is an indicator of earned value BCWP (budgeted cost of work performed). It is the budgeted cost of work that has actually been performed in carrying out a scheduled task during a specific time period. To calculate it, it is necessary to have information on the planned cost of the work to be incurred as of the date of the inspection and the quantity of works actually performed [7].

The group of simple control indicators in this method includes:

- traditional variance – TV:

$$TV = BCWS - ACWP \tag{1}$$

where

$BCWS$ – budget cost of work scheduled,

$ACWP$ – actual cost of work performed.

- cost variance – CV:

$$CV = BCWP - ACWP \tag{2}$$

where
BCWP – budget cost of work performed,
ACWP – as above.

- schedule variance – SV:

$$SV = BCWP - BCWS \tag{3}$$

where
BCWP – as above,
BCWS – budget cost of work scheduled.

In order to perform complex analysis of time and cost deviations, taking into account their impact on the liquidity of the project, the following additional parameters are introduced into the evaluation:

- the monitoring of changes in the assumed cash flow generated by deviation from the planned costs $(T/C)$:

$$T/C = \frac{TV}{CV} = \frac{BCWS - ACWP}{BCWP - ACWP} \tag{4}$$

- the monitoring of changes in the assumed cash flow generated by temporary deviation from the production plan $(T/S)$:

$$T/S = \frac{TV}{SV} = \frac{BCWS - ACWP}{BCWP - BCWS} \tag{5}$$

where
BCWP, BCWS, ACWP, TV, CV, SV – as above.

## 2. Application in engineering

### 2.1. Description of the test schedule

To carry out monitoring of time and cost deviations, a financial and works schedule was used prepared for adding the first-floor to a medical building accommodating the regional blood centre. The construction contract included the following: the demolition of roofing (step 1); earthworks, together with the implementation of the staircase foundation system (steps 2–5); construction of the shell (steps 6–10); internal finishing works (actions 11–14); external finishing works (steps 15, 16); land development (steps 17, 18); repair works on the ground floor of the building (step 19).

The total duration of project including all the above steps was scheduled to be less than three months. Fig. 1 shows the works and financial schedule intended for implementation using the pipelined production method. Analyses were carried out using the Planista Max computer program, in the module 'Registration of works progress'.

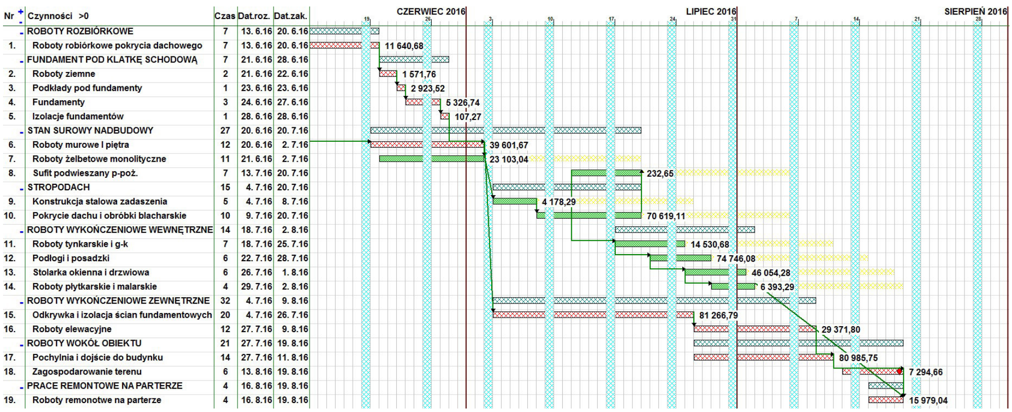


Fig. 1. Beam Gantt schedule for the project. Source: Planista Max

## 2.2. Modelling of time and cost deviations of monitored works

During the study of the impact of time and cost deviations on the financial liquidity of the project, three groups of computer models were developed, giving a total of twelve schedules in the four-scale of growth of the analysed parameter:

- **Models A**: of scenarios exceeding the planned budget costs (C), by 110%, 120%, 130%, 140%, while maintaining the planned duration of the project (S);
- **Models B**: of scenarios exceeding the planned duration of the project (S), by 105%, 110%, 115%, 120% while maintaining the planned budget costs (C);
- **Models AB**: of scenarios exceeding the planned budget costs (C), by 110%, 120%, 130%, 140% while exceeding the planned duration of the project (S) by 105% 110%, 115%, 120%.

The results of the analysis, in the form of percentages, are summarised in Table 1.

A graphical representation of the data is shown in Figures 2–10.

Table 1. Models of schedules of analysed deviations

| Scenario of deviations | Registration stage | BCWP [PLN net] | BCWS [PLN net] | ACWP [PLN net] | T/C [-] | T/S [-] | BCWS-ACWP [PLN net] |
|---|---|---|---|---|---|---|---|
| *A1: S = 100% C = 110%* | 30-06-2016 | 103 639.98 | 107 029.15 | 111 547.94 | **0.57** | **1.33** | **-4 518.79** |
| | 31-07-2016 | 513 825.27 | 515 752.93 | 566 761.25 | **0.96** | **26.46** | **-51 008.32** |
| | 31-08-2016 | 663 932.82 | 663 932.82 | 730 326.10 | **<0,00>** | **<0,00>** | **-66 393.28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A2: S = 100% C = 120% | 30-06-2016 | 103 639.98 | 107 029.15 | 119 455.91 | 0.79 | 3.67 | -12 426.76 |
| | 31-07-2016 | 513 825.27 | 515 752.93 | 619 697.23 | 0.98 | 53.92 | -103 944.30 |
| | 31-08-2016 | 663 932.82 | 663 932.82 | 796 719.38 | 1.00 | <0.00> | -132 786.56 |
| A3: S = 100% C = 130% | 30-06-2016 | 103 639.98 | 107 029.15 | 127 363.87 | 0.86 | 6.00 | -20 334.72 |
| | 31-07-2016 | 513 825.27 | 515 752.93 | 672 633.21 | 0.99 | 81.38 | -156 880.28 |
| | 31-08-2016 | 663 932.82 | 663 932.82 | 863 112.67 | 1.00 | <0.00> | -199 179.85 |
| A4: S = 100% C = 140% | 30-06-2016 | 103 639.98 | 107 029.15 | 135 271.83 | 0.89 | 8.33 | -28 242.68 |
| | 31-07-2016 | 513 825.27 | 515 752.93 | 725 569.19 | 0.99 | 108.85 | -209 816.26 |
| | 31-08-2016 | 663 932.82 | 663 932.82 | 929 505.95 | 1.00 | <0.00> | -265 573.13 |
| B1: S = 105% C = 100% | 30-06-2016 | 99 686.00 | 107 029.15 | 103 639.98 | -0,86 | -0.46 | 3 389.17 |
| | 31-07-2016 | 487 357.28 | 515 752.93 | 513 825.27 | -0.07 | -0.07 | 1 927.66 |
| | 31-08-2016 | 630 736.18 | 663 932.82 | 663 932.82 | 0.00 | 0.00 | 0.00 |
| B2: S = 110% C = 100% | 30-06-2016 | 95 732.01 | 107 029.15 | 103 639.98 | -0.43 | -0.30 | 3 389.17 |
| | 31-07-2016 | 460 889.29 | 515 752.93 | 513 825.27 | -0.04 | -0.04 | 1 927.66 |
| | 31-08-2016 | 597 539.54 | 663 932.82 | 663 932.82 | 0.00 | 0.00 | 0.00 |
| B3: S = 115% C = 100% | 30-06-2016 | 91 778.03 | 107 029.15 | 103 639.98 | -0.29 | -0.22 | 3 389.17 |
| | 31-07-2016 | 434 421.30 | 515 752.93 | 513 825.27 | -0.02 | -0.02 | 1 927.66 |
| | 31-08-2016 | 564 342.90 | 663 932.82 | 663 932.82 | 0.00 | 0.00 | 0.00 |
| B4: S = 120% C = 100% | 30-06-2016 | 87 824.05 | 107 029.15 | 103 639.98 | -0.21 | -0.18 | 3 389.17 |
| | 31-07-2016 | 406 677.73 | 515 752.93 | 513 825.27 | -0.02 | -0.02 | 1 927.66 |
| | 31-08-2016 | 531 146.26 | 663 932.82 | 663 932.82 | 0.00 | 0.00 | 0.00 |
| A1B1: S = 105% C = 110% | 30-06-2016 | 99 686.00 | 107 029.15 | 111 547.94 | 0.38 | 0.62 | -4 518.79 |
| | 31-07-2016 | 487 357.28 | 515 752.93 | 566 761.25 | 0.64 | 1.80 | -51 008.32 |
| | 31-08-2016 | 630 736.18 | 663 932.82 | 730 326.10 | 0.67 | 2.00 | -66 393.28 |
| A2B2: S = 110% C = 120% | 30-06-2016 | 95 732.01 | 107 029.15 | 119 455.91 | 0.52 | 1.10 | -12 426.76 |
| | 31-07-2016 | 460 889.24 | 515 752.93 | 619 697.23 | 0.65 | 1.89 | -103 944.30 |
| | 31-08-2016 | 597 539.54 | 663 932.82 | 796 719.38 | 0.67 | 2.00 | -132 786.56 |
| A3B3: S = 115% C = 130% | 30-06-2016 | 92 295.44 | 107 029.15 | 127 363.87 | 0.58 | 1.38 | -20 334.72 |
| | 31-07-2016 | 434 903.25 | 515 752.93 | 672 633.21 | 0.66 | 1.94 | -156 880.28 |
| | 31-08-2016 | 564 342.90 | 663 932.82 | 863 112.67 | 0.67 | 2.00 | -199 179.85 |
| A4B4: S = 120% C = 140% | 30-06-2016 | 87 824.05 | 107 029.15 | 135 271.83 | 0.60 | 1.47 | -28 242.68 |
| | 31-07-2016 | 407 017.66 | 515 752.93 | 725 569.19 | 0.66 | 1.93 | -209 816.26 |
| | 31-08-2016 | 532 761.78 | 663 932.82 | 929 505.95 | 0.67 | 2.02 | -265 573.13 |

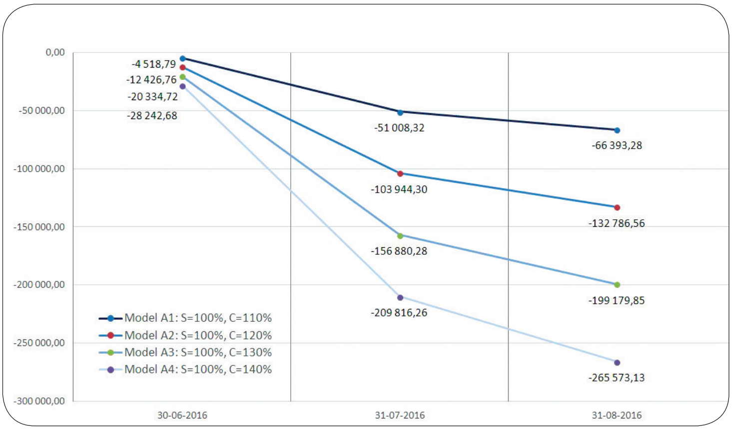


Fig. 2. Financial liquidity of the test project in models A1–A4

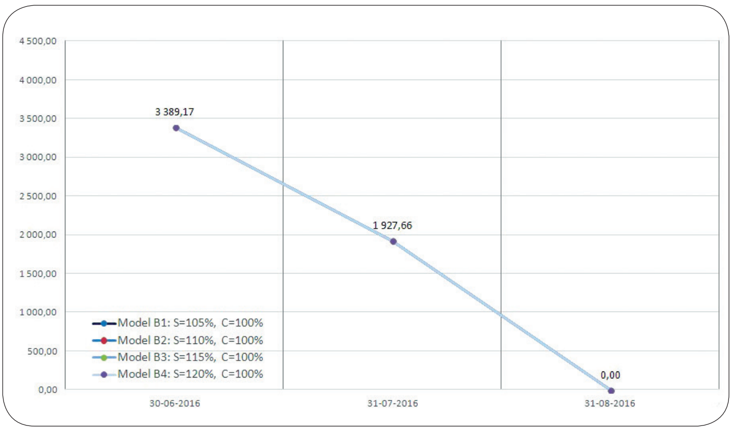


Fig. 3. Financial liquidity of the test project in models B1–B4

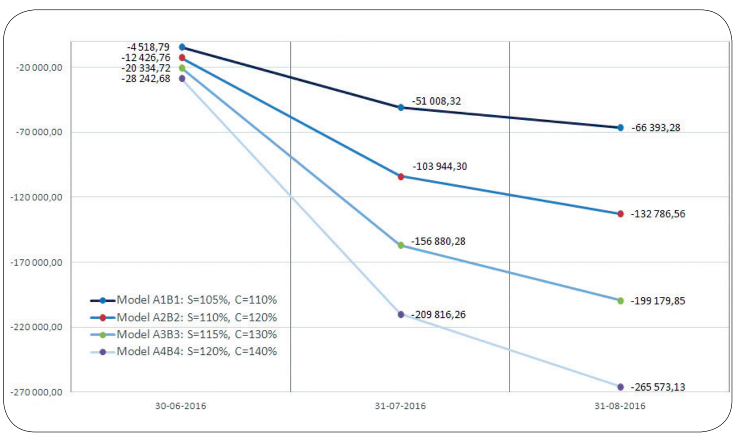


Fig. 4. Financial liquidity of the test project in models A1B1–A4B4

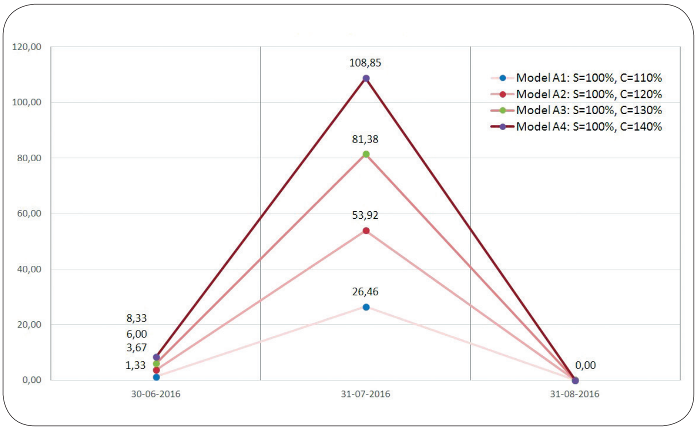


Fig. 5. Monitoring deviations from the assumed time in models A1–A4

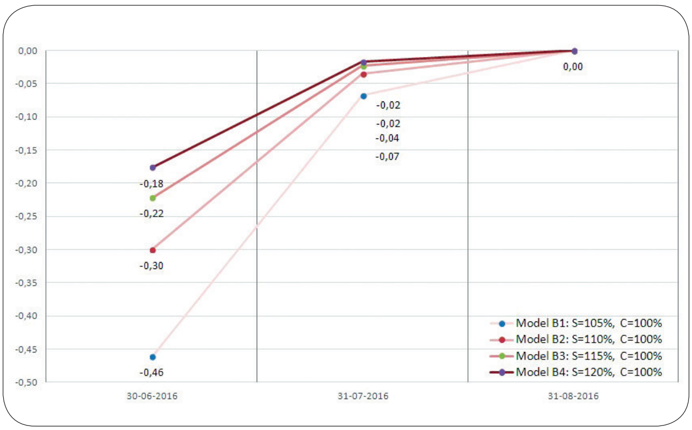


Fig. 6. Monitoring deviations from the assumed time in models B1–B4

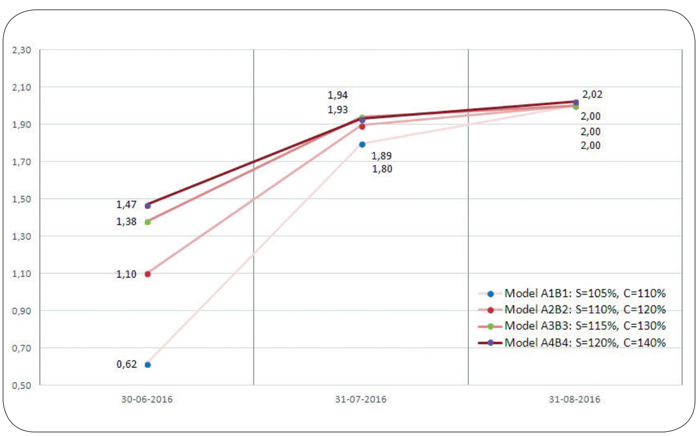


Fig. 7. Monitoring deviations from the assumed time in models A1B1–A4B4

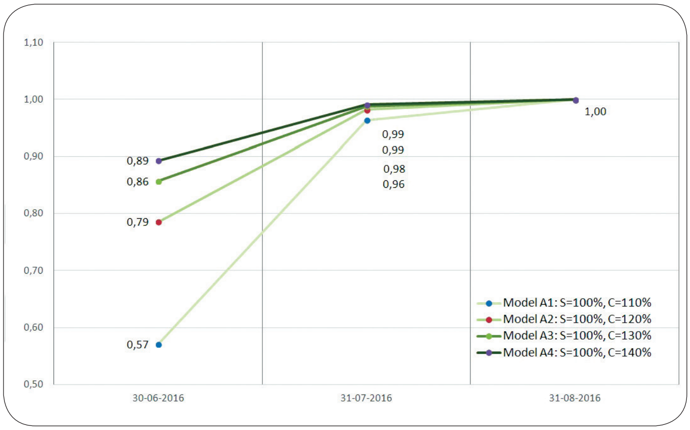


Fig. 8. Monitoring deviations from costs in models A1–A4

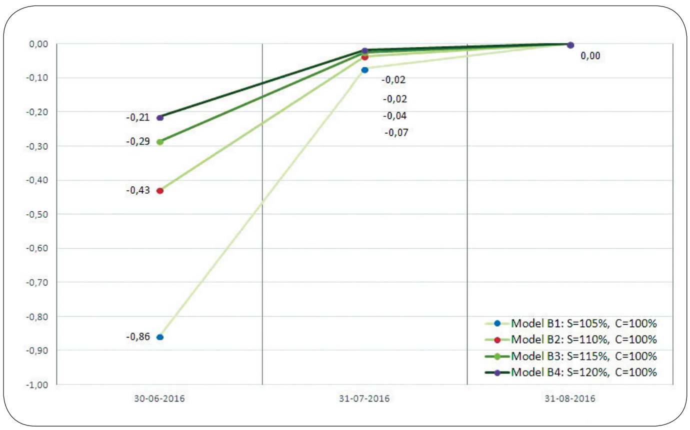


Fig. 9. Monitoring deviations from costs in models B1–B4

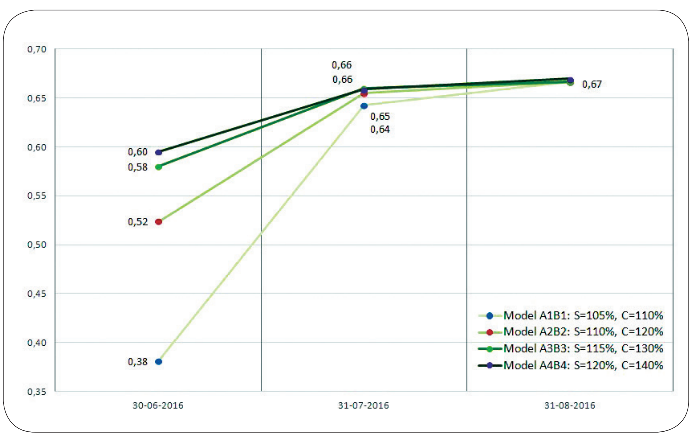


Fig. 10. Monitoring deviations from costs in models A1B1–A4B4

## 3. Conclusions drawn from research and analysis

A three-dimensional analysis of time and cost deviations using the value-added method parameters shows the influence of increase of the delay and budget exceeding value on the financial liquidity of the investment, not included in the classical form of this method.

Analysis of 'pure' liquidity calculated with the difference of costs incurred and planned in different periods (ACWP–BCWS) is illustrated in A model group (Fig. 2), where the increasing amplitude in all three analyzed periods is observed.

In the B model group (Fig. 3) with constant cost incurred, financial liquidity monitoring shows no change resulting from the gradual increase of delays. In AB models (Fig. 4) the amplitude values are equal to the scenarios of the progressive underestimation (A1–A4).

The monitoring of time deviations from the planned schedule, in A model group reflects the influence of increasing cost deviation on the delay of the investment (Fig. 5). The time variances of the investigated schedule for the B model group (Fig. 6) grow in function of time, although in comparison to the declining financial liquidity, the highest negative value was recorded for the first period, decreasing to zero in the third period. An analysis of the complex scenario for models with both delay and underestimation (Fig. 7) gives similar form of monitoring of works execution: in this case, growing value of the time deviation give the result at the level of 2.00 in the third stage – which means twice the difference in liquidity compared to BCWP in that period.

Monitoring of deviations from costs in the A model group (Fig. 8) shows rising values, the highest in the third registration period, calculated by the ratio of disappearance of financial liquidity, in this case, to the difference in BCWP and ACWP values. Analysis of the results of the algorithm monitoring the cost deviation with gradual delay of the schedule (Fig. 9) shows negative deviation values, striving, with increasing time to zero.

The attempt to simultaneously increase the underestimation with modeling of increasing delays (AB models, Fig. 10) gives the value of cost variances as in the A model group, reduced by the delayed execution of works in the schedule.

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