TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
CIVIL ENGINEERING | BUDOWNICTWO

2-B/2014

TOMASZ BAUMANN*, AGNIESZKA DZIADOSZ*, OLEG KAPLIŃSKI*,
MARIUSZ REJMENT**

# RANGE OF APLICATION AND LIMITATIONS OF THE EARNED VALUE METHOD IN CONSTRUCTION PROJECT ESTIMATION

# ZAKRES STOSOWANIA I OGRANICZENIA METODY EARNED VALUE DO OCENY PRZEDSIĘWZIĘCIA BUDOWLANEGO

Abstract

The considerable degree of complexity found in construction work, as well as project susceptibility to unpredictable conditions determines the need of ongoing progress monitoring and continuous time-cost analysis during the execution of work. Financial and material analysis, using the Earned Value method applied to the construction of an Underground Gas Storage Facility, including project risks which occurred during the project, helped to identify the advantages and limitations in application of this method of monitoring work progress.

*Keywords: time-cost analysis, risk assessment, Earned Value Method*

Streszczenie

Znaczny stopień skomplikowania robót budowlanych oraz wrażliwość przedsięwzięć na warunki losowe warunkuje konieczność bieżącej kontroli postępu i permanentnej analizy czasowo-kosztowej w trakcie realizacji. Przeprowadzona w artykule analiza rzeczowo-finansowa, przy wykorzystaniu metody Earned Value budowy Podziemnego Magazynu Gazu, z uwzględnieniem występujących w ramach przedsięwzięcia ryzyk, pozwoliła na wskazanie zalet oraz ograniczeń w stosowaniu wspomnianego sposobu kontroli postępu robót.

*Słowa kluczowe: analiza czasowo-kosztowa, ocena ryzyka, metoda Earned Value*

* M.Sc. Eng, Tomasz Baumann, M.Sc. Eng. Agnieszka Dziadosz, Prof. D.Sc. Ph.D. Oleg Kapliński, Division of Construction Technology and Management, Poznań University of Technology.

** Ph.D. Eng. Mariusz Rejment, Department of Construction Methods and Management, Institute of Building Engineering, Wrocław University of Technology.

## 1. Introduction

**Construction projects** are a subject to a number of factors which interfere with their smooth completion. It is, therefore, important to monitor the progress of work in real time, and systematically analyse any variation in work schedules and project costs compared to the value previously planned, in order to take preventive measures and thus minimize the negative impact of confounding factors. The literature [1–16] quotes the different methods and techniques facilitating the analysis of projects, enabling a comprehensive risk assessment while supporting the decision making process in construction industry. Great attention is drawn to methods which ensure control over projects using a relatively un-sophisticated mathematical methodology, with the simultaneous determination of the likelihood of completing investments on time and within a budget. The Earned Value Method, discussed and exemplified in the example presented in the paper, is one of the most popular methods enabling such monitoring.

## 2. Methodology of Earned Value Management

The Earned Value method is one of the most popular methods used to monitor and control the progress of work. It was initially used for US Government financial analysis. Currently, it is an essential tool used for Project Management and Cost Engineering. It is also popular in the U.S. Department of Defense, NASA and also in the construction industry. Official normalization of the EV method took place in 1967, when the U.S. Department of Defense introduced the C/SCSC standard (Cost/Scheduling Control System Criteria) describing the 35 criteria which should be applied to control cost and work schedules. Between 1995 and 1998, the EVM was adapted in the industry under the heading of ANSI EIA 748-98 standard. Here, in contrast to the traditional approach of cost comparison, the scope of the work actually carried out on site is taken into account. The analysis is based on several measurements utilizing appropriate indicators. Measurements are taken at regular intervals, e.g. at the end of the month, tracking the trends and variations of those indicators. Indirectly, we can use EVM to control risk in the context of exceeding project costs and failure to meet the deadline of completion of the investment. As the authors of the publication [2–5, 11, 12, 15, 16] stress, the primary purpose o EVM is to measure the progress of the project, predict its total cost and completion date, as well as analyze any inconsistencies between the schedule and the budget.

## 3. Analysis of construction of the Underground Gas Storage Facility

Implementation of the analysed contract was planed in “the DESIGN and BUILD system”. The system assumes that the Contractor is expected to develop detailed technical documentation of structures to be built and select technologies and technical equipment. In theory, it allows the Client to reduce the number of highly specialized staff and the total cost of the task, and allows the Contractor to retain greater flexibility and select both technically and economically optimal solutions. In reality, it is a way of transferring the risks associated with the elaboration of the design documentation, into the Contractor, while the Client is hardly accountable for delays and additional costs associated with this part of the task.

### 3.1. Hazards and risks

Due to the nature and complexity of construction work carried out during the realization of the Underground Gas Storage Facility (USF), many factors came up, affecting both the timeliness and finances linked to the project. A list of examples of the hazards and risks sources is presented below:

- Limited time spent by the Client on final execution of construction work which caused delays at the design phase and followed through into the implementation period. Delays in the design work which directly translated into delays in the commencement of construction work, and not only regarding the structure under construction but also related construction works. The need to break up the design work and delegate it to a number of design offices caused numerous coordination problems;
- High level of expertise expected from companies involved in the construction made it necessary to set up a consortium. The division of work, necessary to determine the scope of responsibility of each member of the consortium, has caused a tendency to restrict planning to individual portions of the task, not taking the needs and potential of other parties into account;
- Limited space on the building site, in connection with the number of companies and individuals involved, limit the possibility of the simultaneous storage of materials (forcing the need for careful scheduling of deliveries). This generated inconveniences associated with, for example, organization of the site facilities or availability of parking spaces;
- The entire design and construction process was subordinated to the technological process. Technological equipment delivery and installation delays had a disproportionately large impact on the contract, in comparison to the time required for the installation, and became (in addition to delays in designing work) the most serious reason for delays in relation to the schedule;
- Considerable scope of construction work covered by the contract meant the need to involve enormous human resources. In reality, it meant several companies organized in a structure with several levels of subcontracting relationships. Apart from the coordination problems, delays on the work front caused by one of the companies very often made it difficult, or even impossible for the others to work.

### 3.2. Construction work and financial analysis of the project

The starting point for the analysis, using the EVM, was the construction work and financial schedules or their parts (tasks organized over time with assigned financial resources). On this basis, with respect to the assumed duration, the base BCWS and cost curve of planned costs (Budgeted Cost of Works Scheduled) was defined, showing increasing costs of tasks, while additional parameters were defined (including SV and SPI indicators for each accounting period). The analysis was performed for both the entire project and for each of the built structures separately, taking into account various random factors.

### 3.2.1. Modifications in BCWS curve for the construction of the USF

The first factor threatening the smooth realization of the USF construction project appeared as early as in the first months of construction. Despite making the technical designs of buildings available (including the administrative building, the sources building) for execution, the design work on the main technological sequence had not started. The developed concept required such extensive changes in relation to that which had been previously presented by the Client that it became necessary to work out an alternative technical design and apply for a replacement building permit. The situation was made more serious by delays in the reporting data regarding machinery and equipment by the members of the consortium. Subsequent updates of material and financial schedule, issued in the form of revisions, were produced during the course of construction work (Fig. 1).

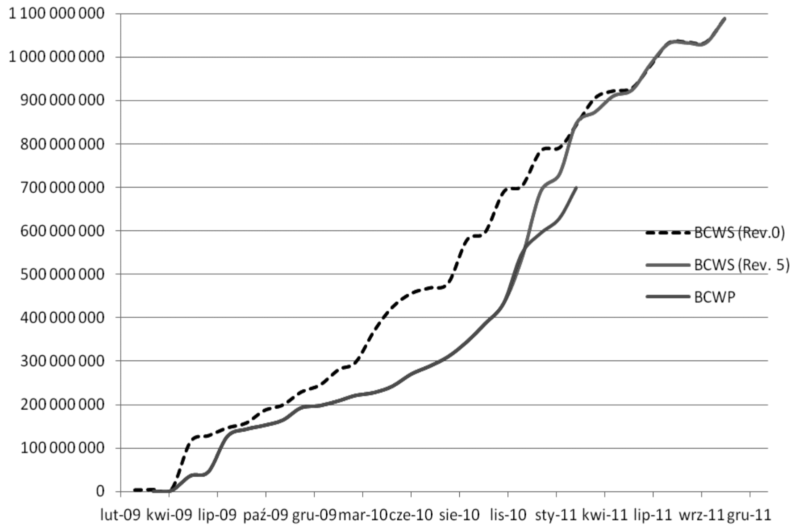



Fig. 1. The impact of subsequent revisions of material and financial schedule on the shape of the BCWS curve. The progress of construction work in the end of March 2010

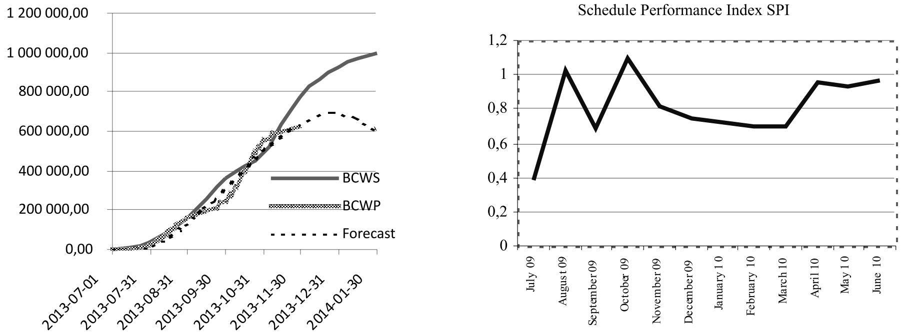
By mid contract, SV reached almost 10% of the contract value, and SPI decreased (PV = 429 372 353,93 PLN, EV = 306 898 504,63 PLN SV = –122 473 849,30 PLN, SPI = 0.71). The surge in progress at the end of 2009 is a good example of the sensitivity of EV method to unreliable data, as the described increase resulted primarily from the financial settlement of work at the end of the year which, in fact, would actually be completed at a later date. Almost zero revenue in January and February 2010 is proof of such a source of the surge. In the second half of 2010, as a result of the involvement of an additional design office, most of the technical drawings were completed and submitted for execution, resulting in an accelerated the pace of work. Better indicator values seen in the middle of that year could be noted (PV = 676 361 628,13 PLN SV = 643 542 647,78 PLN SV = –32 818 980,35 PLN, SPI = 0.95), which confirms the increase of the curve BCWP in Figure 1. Despite the implementation of the recovery plan (another revision of the schedule) and the delivery of the majority of equipment, progress was far from what was expected. The situation was further complicated by cold and snowy winter weather, followed by a thaw, which paralyzed the construction site for two weeks and substantially damaged the temporary access roads. At the end of March 2010, the indicator values were as follows: PV = 848 081 324,58 PLN, EV = 699 161 945,27 PLN SV = –148 919 379,31 PLN, SPI = 0.83 (6 months before the scheduled deadline of work).

### 3.2.2. The impact of bankruptcy risk of a company on the construction of the warehouse-service building

The warehouse-service building was selected for detailed analysis in order to present risks resulting from disruptions and discontinuations of construction work as a result of a subcontractor's declaration of bankruptcy. Procedures related to the choice of a replacement subcontractor, and new pricing for the remaining scope of construction work resulted in a two month discontinuation of construction work and an the increase of the final cost.

Although the construction work started with a slight delay in relation to the schedule, all the foundations and 50% of backfills were completed in August. All steel structure elements were delivered to site, a large part of which (mainly columns) were pre-assembled. This resulted in the liquidation of the initial delay, work was now just ahead of schedule, as indicated by SPI at 1.03 (PV = 154 637,17 PLN, EV = 158 711,65 PLN SV = 4 074,48 PLN, SPI = 1, 03). This indicator is not, however, completely reliable, and again demonstrates the sensitivity of the EV method to the manner of entering data. A 100% delivery of steel structure elements was considered to be a part of the completed work, in spite of the fact that, actually, only about 60% of the steel structure had been installed. This significant value of structural elements resulted in an overestimate of the achievements. In such cases, in the EVM analysis only values supplied materials in proportion to the amount actually installed, so only this should be take into account. With such an approach, the SPI value decreased to 0.95. The projected work completion date was the end of October 2009 (which meant two months ahead of schedule). After a very successful August and September 2009 a significant slow-down in progress, primarily due to a delay in laying the flooring and the building of brick partition walls (PV = 359 118,03 PLN, EV = 246 258,47 PLN SV = –112 859, 56 PLN, SPI = 0.69). The projected completion date, consistent with that assumed – EACT = 3.46 months. In November, the progress of construction work was so slow, that it seriously threatened the completion date, which raised management concern. The subcontractor was requested to submit and implement a recovery plan. Then, the indicators were as follows: PV = 776 626,42 PLN, EV = 627 364,76 PLN SV = –149 261,66 PLN, SPI = 0.81. January 2010 marked an actual interruption of work by the subcontractor. The only work carried out during this month (completion of wall panels installation, and the roof) was done by a previously hired specialized company. At the end of the month, the subcontractor informed the main contractor that they would be declaring bankruptcy and left the construction site (PV = BAC = 1 000 000,00 PLN, EV = 716 370,21 PLN SV = –283 629,79 PLN, SPI = 0.72). The procedures relating to the selection of a new subcontractor, as well as the winter period resulted in the resumption of work as late as in April 2010.

The example discussed above shows the way the EV method can be used to recognize danger signals threatening the continuity of construction work. Steadily decreasing SPI values at the end of the year, in conjunction with the flattening of the BCWP curve, clearly indicated a significant decrease in the pace of work, jeopardizing the timeliness of construction – c.f. (Fig. 2).




Progress in November 2009. Forecast line (trend) drawn using a second degree polynomial

Changes in SPI in periods.

Fig. 2. Progress in subsequent accounting periods

## 4. Strengths and limitations of the Earned Value Method – the example of USF construction

The Earned Value Method, used in this article to perform a construction work scope and financial analysis of a construction project, is relatively widespread abroad. It had been developed to American and Australian standards [15, 16]. Despite many advantages and the enormous potential, more and more attention is paid to its certain limitations and inaccuracies:

- Referencing deviations from schedule to cost units, and un timed units (a modified method – Earned Schedule);
- Difficulty in analyzing EVM indicators due to change of the so called baseline in view of events in the course of construction work. In view of this, a certain discipline in the construction and maintenance of the schedule is required. This is the case in implementation of innovative projects, where there might be changes and unforeseen events. Then the scope of the budget and the schedule is changed and this, in turn, affects the project completion estimates;
- Subjective way of assessing work progress which, in extreme cases, may lead to deliberate falsification of data in order to present the desired image (for example, desirable from the viewpoint of the board);
- Regarding contracts exceeding completion time limit, there is no clear accountability for contractual penalties which may be charged by the Client;
- Limited applicability of the EVM may result in choosing the flat rate method for contract accounting, widespread in the construction industry. With this approach, it is impossible to define the majority of method indicators, and its usefulness is limited mainly to the fact that it analyzes progress and timeliness of work. Then, this method is only a secondary source of information, indicating some trends rather than accurately forecasting future revenues;

- In the event of changes in the work order, in particular, high percentage ranges of contract value, the schedule and BCWS curve needs to be modified respectively, and only on that basis the actual progress of works should be evaluated;
- According to the theory, this method should take only the tasks already performed (e.g. using milestones) into account. This means that a lot of tasks close to completion can not be taken into account, which will decrease estimates of progress. Therefore, it is advisable to divide the project into smaller parts, and determine a percentage of task progress.

## 6. Conclusions

It seems that, apart from showing errors in the organization and management of the project related to construction of the Underground Gas Storage Facility, minor inaccuracies should be highlighted when using the Earned Value Method to supervise construction contracts based on flat rate pricing (BCWP curve overlaps with ACWP), however, due to the relatively high sensitivity of the method, it is highly susceptible to entered data. In the situation described, the EV Method should be regarded rather as complementary and supportive to other methods, as well as a convenient way of synthetic presentation of data, for example, to the board. Nevertheless, all these inconsistencies do not diminish its merits and potential.

## References


[1] Bauman T., *Analiza rzeczowo-finansowa Podziemnego Magazynu Gazu*, praca dyplomowa magisterska, 2013.

[2] Czarnigowska A., *Earned value method as a tool for project control*, Architecture and Building (3), 2008, 15-32.

[3] Czarnigowska A., Jaskowski P., Biruk S., *Project performance reporting and prediction: extensions of Earned value management*, International Journal of Business and Management Studies 1, Vol. 3, 11-20.

[4] Czarnigowska A., Sobotka A., *Metoda planowania i kontrolowania realizacji przedsięwzięć budowlanych*, Górnictwo i Geoinżynieria, Rok 35, Zeszyt 1, 2011, 37-56.

[5] Dałkowski B., *W trosce o publiczne pieniądze – zarządzanie projektami metodą Earned Value*, Materiały z III Konferencji Project Management, 1-8.

[6] Dziadosz A., *Przegląd wybranych metod wspomagających analizę ryzyka przedsięwzięć budowlanych*, Przegląd Budowlany, nr 7–8, 2010, 76-77.

[7] Gajzler M., Dziadosz A., Szymański P., *Problematyka wyboru metody wspomagającej podejmowanie decyzji w budownictwie*, Czasopismo Techniczne 1-B/2010, 69-84.

[8] Kapliński O., *Development and usefulness of planning techniques and decision-making foundations on the example of construction enterprises in Poland*, Technological and Economic Development of Economy, Vol. 14, No. 4, 2008, 492-502.

[9] Kapliński O., *Risk analysis of construction projects: From risk identification to contingency timetable*, SEMC 2010: The Fourth International Conference on Structural Engineering, Mechanics and Computation, Cape Town, South Africa, 6–8 September 2010, [In:] A. Zingoni (Ed.), *Advances and Trends in Structural Engineering, Mechanics and*

*Computation*, CRS Press Balkema, Taylor & Francis Group, London 2010, Abstract: 268, paper CD: 1051-1054.
[10] Kapliński O., Dziadosz, A., Zioberski J.L., *Próba standaryzacji procesu zarządzania na etapie planowania i realizacji przedsięwzięć budowlanych* (An attempt of management process standardisation at the stage of planning and implementation of construction projects), Zeszyty Naukowe Politechniki Rzeszowskiej, Budownictwo i Inżynieria Środowiska, 58, (3/11/I), 2011, 79-100 (in Polish).
[11] Połoński M., *Kontrola kosztów budowy metodą EVM jako metoda ograniczenia ryzyka przekroczenia planowanego budżetu*, Przegląd Budowlany, nr 10, 2010, 46-52.
[12] Sobotka A., Grochal D., *Sterowanie realizacją przedsięwzięcia budowlanego z wykorzystaniem metody planowania i kontroli przebiegu robót*, Problemy przygotowania i realizacji inwestycji budowlanych, Warsztaty Inżynierów Budownictwa, Wydawnictwo Wacetob Sp. z o.o., Puławy 2009, 111-120.
[13] Turskis Z., Gajzler M., Dziadosz A., *Reliability, risk management, and contingency of construction processes and projects*, Journal of Civil Engineering and Management, Vol. 18 (2), 2012, 290-298.
[14] Zavadskas E.K., Turskis Z., Tamošaitiene J., *Risk assessment of construction projects*, Journal of Civil Engineering and Management 16 (1), 2010, 33-46.
[15] DOD Earned Value Management Implementation Guide, Washington: United States of America Department of Defense, 1997.
[16] AS 4817-2006, Project performance measurement using Earned Value.