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Application of Earned Value Method to Progress Control of Construction projects

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Abstract

Earned Value Method (EVM) is the efficient and well known tool for project management. Application of the method together with complementary - dedicated for EVM - known approaches, make the method well adjusted for use on dynamic and multidisciplinary construction site. The concept of Schedule Forecast Indicator to be used as the addition to EVM has been developed to support site managerial decisions concerning variation orders.

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Keywords: Earned Value Method; construction project management; variation order.

1. Introduction

It is still difficult to get the exact answer about the real progress of many construction projects. A construction project is perhaps one of the most complex and dynamic processes if to consider business and engineering activities. Engineers usually express the progress of works referring to the time schedule or to the cost plan. Since the changes or variation orders are normal practice in real construction projects, more integrated method is needed to describe the true status of a project. According to [1], the Earned Value Method (EVM) is recommended as the global standard for project performance measurement. The method really integrates scope, cost and schedule measures, and could give good picture of current project status at the date of control. The concept of implementation the EVM into the cost control and even to overall performance measurement of construction projects have been presented by many authors [3, 4, 5, 7].

Application of the EVM in the construction site management practice do require systematic register of time and cost data (usually once a week) in order to get the two following values: ACWP which is Actual Cost of Work Performed and BCWP – Budgeted Cost of Work Performed. The third required value, namely BCWS – Budgeted

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Cost of Work Scheduled can be defined before start of works, based of the time schedule of all works and the respective cost plan (Fig.1).

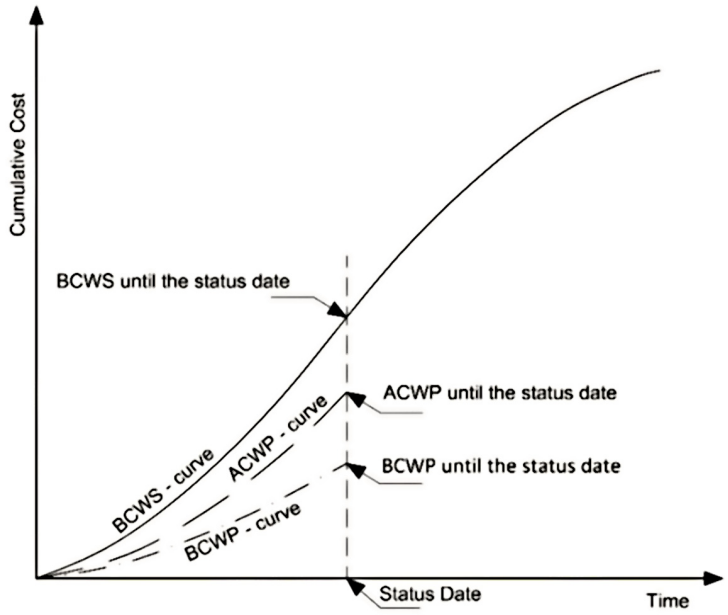

Fig. 1. Three basic curves used in the EVM.

Effective managing the construction site with supporting decisions by the EVM needs use of some additional managerial instruments which enable for quick and efficient cost/time data identification needed for each date of control. Firstly, the two corresponding documents: the cost plan and the breakdown of lump-sum price are needed. Without those documents, which should present breakdown of all works and costs in identical orders, one would have spent many hours to calculate especially BCWP value. Moreover, since variation orders happen nearly every week, especially in large construction projects, it would be beneficial to be well prepared to reduce eventual Cost Variance (CV=BCWP-ACWP) and Schedule Variance (SV=BCWP-BCWS), which are the two important measures of the EVM. Reducing SV and CV means simply to catch up the target final cost and the deadline date of the project. In order to do it, the site manager should know all the critical works to relocate people and other resources - in effective way – to critical activities. Thus, except of the cost plan and the breakdown of lump-sum price, the CPM network, considering the same activities as listed in the two other mentioned project documents, is required for efficient use of the EVM on site. As an effect of systematic use of the EVM, the site manager can get every week the up-dated prognosis on cost variance at completion and schedule delay at completion (Fig. 2)

2. Modification of EVM by additional approaches

The core concept of the EVM is of deterministic nature. Several authors proposed some additional approaches to model the construction works in probabilistic way [2, 9, and 11]. More often, the Monte-Carlo simulation has been used to generate the three shapes of the basic EVM curves, referring to: minimum, maximum and most likely of BCWS, ACWP and BCWP values. It should be noted, that even the construction site managers use powerful computers in their daily practice, but correct application of the Monte-Carlo simulation and use of function of distribution of probability which is adequate for particular construction works would be successful provided the software is dedicated for a given type of a construction project. The other group of EVM modification approaches is focused on shaping the original EVM to controlling the project time in better way, than it is possible by use of the original edition of the method. It is worth to notice, that originally the EVM was developed for both, cost and time management, but on the other hand, most of construction project managers use it for cost management, only.

According to EVM, even the measures as SV (schedule variance), which is used to indicate the schedule efficiency, is expressed in a monetary units. Moreover, the EVM does predict future performance of the contractor based on past performance, examined till the status date. But, remaining works of the construction project could be subjected to new risks, not recorded before the status control date. So, the EVM should be modified, taking into account also the future risks, in order to be successfully used for project time management.

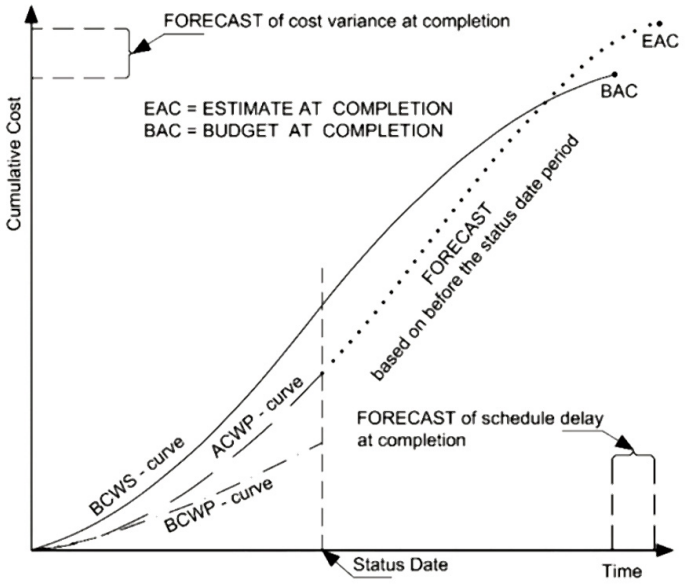

Fig. 2. Forecast values provided by EVM.

Very practical oriented integration of EVM with risk management tools, considering both past performance and future risks, have been published in the paper [6]. Other modification approaches, also focused on project duration forecasting, have been developed and published in papers [8, 10]. So, we have available several modified Earned Value Methods suitable for assessing construction projects, considering to similar extend both, project duration and project cost.

3. Schedule Forecast Indicator

The Earned Value Method could also be used for supporting the decision about implementing design changes in various project phases. It is known, that one design change usually – as a consequence – brings next project changes, which may be difficult to predict before the initial change implementing. The Schedule Forecast Indicator (SFI), presented here, is a new formula (1) dedicated for construction project managers as a supplementary managerial tool to be used in conjunction with the EVM.

$$SFI = \frac{a \times \sum_{START}^{STD}(\mathrm{t_c}) + \sum_{START}^{STD}(\mathrm{t_{nc}})}{(a+1)\sum_{START}^{END}(\mathrm{t_c} + \mathrm{t_{nc}})} \tag{1}$$

where:

$$a = \frac{\sum_{START}^{END}(\mathrm{t_{nc}})}{\sum_{START}^{END}(\mathrm{t_c})}, \qquad \sum_{START}^{STD}(\mathrm{t_c}) \text{ - total duration of all critical activities completed by the Status Date,}$$

$\sum_{START}^{STD}(t_{nc})$ - total duration of all not critical activities completed by the Status Date,

$\sum_{START}^{END}(t_{nc})$ - total duration of all not critical activities,

$\sum_{START}^{END}(t_{c})$ - total duration of all critical activities.

The objective of SFI is to present a value expressing the chance for successful cancellation of the delay occurred at various phases of the project. The construction project manager before making a decision about implementing a new design change should always consider if the project target cost and the project end date would be met. Certainly, it is much easier to cancel any disturbances generated by the design change in early stages of the project than in its late phases. What's more, probability of effective cancellation of any delays borne by a design change depends on the number of critical and not critical remaining activities, i.e. activities to be executed after the Status Date and before scheduled end of the project, with respect to all project activities, i.e. activities to be executed during the whole project duration. Obviously the number of critical activities is more important value than number of not critical activities, so the respective weight factor *a* has been proposed for the SFI formula. Effective application of decision supporting SFI value can be possible after the CPM network for the project is ready, and the network should include the same activities as presented in the breakdown of lump-sum prices and the same, as in the cost plan.

The SFI concept was used for supporting the managerial decision making process during recently completed construction of multifamily apartment building in Poland (7 floors, 70 apartments). The project duration was 18 months. It was known from the beginning that many details would have to be designed during the construction time, so a considerable number of variation orders was forecasted. On the other hand, the delay of project completion was not acceptable because many purchase contracts have been signed with apartment buyers, shortly after project begin. So, some recommended variation orders have been even not implemented because of too big risk of delay that could be caused by their approval. The decisions about implementation of variation orders were effectively supported by the diagram presenting distribution of SFI value over the whole project duration (Fig. 3).

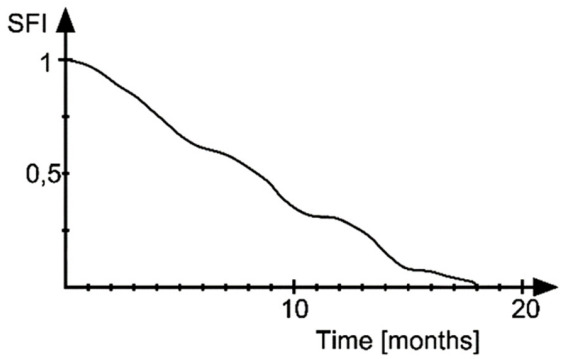

Fig. 3. Distribution of Schedule Forecast Indicator over 18 months of project duration.

The risk concerned with implementation of any variation order was evaluated with respect to possibility of no delayed completion of the project. Distribution of SFI curve was like a guide for the project manager, presenting the chance for successful cancellation of eventual delay that might be caused by a considered change implementation. The successful "handling" with variation orders, especially those, which can be avoided, was possible thanks to use SFI guiding curve, but also to the CPM network available for the whole project, as long as other site monitoring documents, like breakdown of lump-sum price and cost plan, all of them presenting identical split of the whole scope of works into elemental activities.

4. Conclusions

Earned Value Method can be successfully used not only for cost management of construction projects, but also – using some additional approaches - for project duration management, even if many variation orders should be considered during the project execution period. A considerable number of additional approaches adjusting the core shape of the EVM to very dynamic nature of construction projects make that method very adequate for use in real construction site management practice. The Schedule Forecast Indicator is simply and effective decision supporting value recommended for use on site, when the new variation order is to be considered with respect to conservative schedule requirements.

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