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Impact of sensitivity information on the prediction of project's duration using earned schedule method

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Abstract

Recently, the prediction of project duration has been investigated in earned value management (EVM) using three earned value methods, planed value (PVM), earned duration (EDM) and earned schedule (ESM). The investigation has shown that ESM method outperforms on average the other two methods and fails in case of wrong warning coming from non-critical activities which suffer from delays and/or ahead of schedule. The objective of this paper is twofold: first, we study the impact of the activities' sensitivity information on the forecasting accuracy of the ESM method. Second, we test the claim that in normal conditions the project performance indicator provided by ESM at higher work breakdown structure is reliable. More precisely, activity based sensitivity measures are used as weighing parameters of the activities to improve the schedule performance of a project by removing or decreasing the negative effect of wrong warning of the non-critical activities. The computational results of a simulation study on a big benchmark projects reveal that the sensitivity information are capable of improving the forecasting accuracy of the ESM method.

Keywords: Earned value management; Project duration forecasting; Earned schedule; Critical activities; Time sensitivity measures

1. Introduction

Earned value management (EVM) is a management technique for project performance monitoring. A detailed explanation of EVM basis can be found in Anbari (2003), Fleming and Koppelman (2010) and PMI (2008). Based on the earned value parameters, to the best of our knowledge, only three project duration forecasting methods are in the literature: the planned value method (PVM) developed by Anbari (2003), the earned duration method (EDM) developed by Jacob (2003) and extended by Jacob and Kane (2004), and the earned schedule method (ESM) developed by Lipke (2003). Recently, the main concepts of EVM and the three methods have been reviewed with an illustrated example in Vanhoucke (2010a). Vandevoorde and Vanhoucke (2006) give a summary of time measurement and the aforementioned forecasting methods. They also compare the three methods and test them to a simple one activity project and a real-life data set. Based on these data, they conclude that the three methods give similar results in the early and middle stages. However, the ESM provides better results for monitoring project progress at the final stage of the project. Vanhoucke and Vandevoorde (2007a) also investigate the reliability of the three EVM methods to forecast a project's final duration on a wide and diverse set of fictitious project networks. They conclude that the ESM indeed performs on average better than the PVM and EDM methods in case of no false warning effects coming from non-critical activities. Therefore, in the sake of helping the professional community in getting a reliable prediction and avoiding managerial effort spending in false warning, studying the impact of the activities' sensitivity information on the forecasting accuracy of the ESM method is the first objective of this paper.

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Jacob and Kane (2004) argue that the well-known performance measures of EVM are true indicators for project performance as long as they are used on the activity level, and not on the control account level or higher work breakdown structure (WBS) levels. Whereas, in Vandevoorde and Vanhoucke (2006) and Vanhoucke and Vandevoorde (2007a), the EVM performance measures are calculated on the project level, and not on the level of each activity. They claim that effects (delays) of non-performing activities can be neutralized by well-performing activities (ahead of schedule) at higher WBS levels. Testing the validation of this claim is the second objective of this paper.

Because of doing the project performance measurement at the cost account level which might result in covering potential problems, project performance indicators provided by ESM act as early warning signals to detect problems and/or opportunities. Based on these indicators, Vanhoucke (2010b) investigates whether the activity sensitivity measures are able to distinguish between highly sensitive and insensitive project activities in order to steer the focus of the project tracking and control phase to those activities that are likely to have the most beneficial effect on the project outcome. More precisely, he uses the following four activity sensitivity measures from Martin (1965), Williams (1992) and PMI (2008) to guide the managerial corrective actions when anticipating delays in the project: 1 — criticality index (CI), 2 — significance index (SI), 3 — schedule sensitivity Index (SSI), and 4 — cruciality index (CRI) based on: 4.a — Pearson's product-moment (CRIr), 4.b — Spearman's rank correlation (CRIρ), and 4.c — Kendall's tau rank correlation (*CRIτ*). For more information the formulas of the four measures and how to compute them are described with an illustrated example in Vanhoucke (2010b). He extends his work in Vanhoucke (2011a) in which he presents two alternative project tracking methods. First, the top-down project tracking method relies on earned value management project performance data (based on ESM) that triggers to the need for corrective actions that require a drill down to the lowest WBS levels. Second, the bottom-up tracking method is based on schedule risk analysis that reveals sensitivity information of each activity and assumes that the focus should lie on only the highly sensitive parts of the project. His computational experiment shows that a top-down project tracking approach is highly efficient for project networks with a serial activity structure while a bottom-up approach performs better in a parallel structured project network. Moreover, based on a Monte-Carlo simulation study on fictitious and empirical project data (Vanhoucke, 2011b), the topological structure of a project network considers a main driver for the variability and efficiency of the project control phase. Also, the efficiency of project control can be significantly improved by combining a top-down and a bottom-up project control approach which consider a strong reason of this study. In the same direction Lipke et al. (2009) use the statistical prediction and testing methods to improve the reliability of ESM in forecasting the final cost and duration.

Motivated by the above studies and the common knowledge that the critical path analysis gives a good project duration estimate (see, Schonberger, 1981; Gutierrez and Kouvelis, 1991), in this paper, we investigate the impact of emerging activities' sensitivity information into the earned value calculations on the project time performance indicator of ESM method. In doing so, the influence of activity based sensitivity measures on the forecasting accuracy of ESM is examined in three levels: 1 — overall forecasting accuracy, 2 — during project progress, and 3 — at a certain project network structure.

The paper is organized as follows: in Section 2 a proposed methodology to combine activity sensitivity information in the earned schedule calculations is explained. A simulation study, the used project dataset and the simulation scenarios, is described in Section 3. Section 4 shows the forecasting accuracy formulas and the computational results. The computational results are as follows: the impact of the sensitivity measures on the accuracy of the project duration is investigated in Section 4.1. Section 4.2 and Section 4.3 show the impact of the sensitivity measures during the project progress and at different project network structures on the accuracy of the prediction respectively. Section 5 is left to conclusions.

2. Proposed methodology

The forecasting of a project duration using the ESM can be estimated by the following equation: $EDAC = AT + \frac{PD-ES}{SPI(t)}$, where the future performance of the remaining time, $PD-ES$, can be corrected towards the current *SPI* (*t*) trend. where:

EDAC	estimated duration at completion.
AT	actual time, is the duration at which the *EV* accrued is recorded.
PD	project planned duration.
ES	earned schedule, $= t + \frac{EV-PV_t}{PV_{t+1}-PV_t}$, where *t* satisfies that $EV \geq PV_t$ and $EV < PV_{t+1}$. ES identifies the time at which the amount of earned value (*EV*) accrued should have been earned (Lipke, 2003).
PV_t	planned value at time instance t, $= \sum_i PV_{i,t}$, where $PV_{i,t}$ is the planned value of activity *i* at time instance *t*.
EV	earned value at actual time, $= \sum_i EV_{i,AT}$ where $EV_{t,AT}$ is the earned value of activity *i* at actual time *AT*.
SPI (*t*)	schedule performance index,=*ES*/*AT*.

In this study, we try to improve the forecasting accuracy of ESM by removing/decreasing the false warning effects caused by the non-critical activities. The proposed methodology to fulfill this aim is to merge the sensitivity information into the earned value calculations as follow. Let α_i be the weighting factor of activity *i*, $EV_\alpha = \sum_i \alpha_i.EV_{i,AT}$ be the weighted earned value at actual time, and $PV_{\alpha,t} = \sum_i \alpha_i.PV_{i,t}$ be the weighted planned value at time instance t. The earned schedule, ES_α, and schedule performance index, *SPI* (*t*), based on the weighting factor α can be easily calculated. Also, the project duration can be estimated using ESM_α at weighting factor α, (i.e. $EDAC_\alpha$).

In this study, the four sensitivity measures mentioned in the above section will be used as weighting factors. Formally, $\alpha \in \{1, CI, SI, SSI, CRI_r, CRI_\rho, CRI_\tau\}$, where α = 1 means that the project duration estimation is based on no distinction among activities and all the activities have an equal weight in the total earned value calculations. That is, ESM1 ≡ ESM.