Measuring the Accuracy of Earned Value/Earned Schedule Forecasting Predictors

By Mario Vanhoucke and Stephan Vandevoorde

Abstract

Earned value systems have been setup to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery, and total project budget. Although earned value systems have been proven to provide reliable estimates for the follow-up of cost performance within certain project assumptions, it often fails to predict the total duration of the project. In this article, we give a brief overview and summary of a simulation study that investigates the potential of three earned-value-based methods to forecast the final project duration. The study assumes a project setting where project activities and precedence relations are known in advance and does not consider fundamentally unforeseeable events and/or unknown interactions among various actions that might cause entirely unexpected effects in different project parts. This paper is the first in a sequence that summarizes the results of the large simulation study initiated by Vanhoucke and Vandevoorde (2007). Each paper will discuss and highlight an aspect of the simulation study.

The planned value method (Anbari, 2003) and the earned duration method (Jacob, 2003) are two well-known methods that rely on the traditional schedule performance indicator SPI (= EV/PV) and can be used to predict a project's final duration. Lipke (2003) has criticized these approaches and has presented a straightforward extension, known as the earned schedule technique, which claims to overcome some drawbacks of the traditional earned value methods when predicting a project's final duration. More precisely, the earned schedule method has been developed as a criticism on the use of the classic SV and SPI metrics since they give false and unreliable time forecasts near the end of the project. Instead, Lipke (2003) provided a time-based measure to overcome the quirky behavior of the SV and SPI indicators, and calculates two alternative schedule performance measures (referred to as SV(t) and SPI(t)) that are directly expressed in time units. This novel method relies on similar principles of the earned value method, and can be calculated as follows:

Find t such that $EV \geq PV_t$ and $EV < PV_{t+1}$

$$ES = t + (EV - PV_t)/(PV_{t+1} - PV_t)$$

with

- ES Earned Schedule
- EV Earned Value at the actual time
- PV_t Planned Value at time instance t.

Consequently, the cumulative value for the ES is found by using the EV to identify in which time increment t of PV the cost value for EV occurs. ES is then equal to the cumulative time t to the beginning of that time increment, plus a fraction $(EV - PV_t) / (PV_{t+1} - PV_t)$ of it. The fraction equals the portion of EV extending into the incomplete time increment divided by the total PV planned for that same time period, which is simply calculated as a linear interpolation between the time-span of time increment t and t + 1.

Since the introduction of the earned schedule concept by Lipke (2003), other authors have investigated the potential of the new method in various ways. Henderson (2003) has shown the validity of the ES concepts on a portfolio of six projects. We (Vandevoorde & Vanhoucke, 2006) were the first authors to compare the three methods and test them to a simple one activity project and a real-life data set. Moreover, we summarized the often confusing terminology used in the earned value literature, which will be used throughout this paper.

In Vanhoucke and Vandevoorde (2007), we argue that the promising results of these various research efforts need be taken with a critical eye. Inspired by the shortcomings of the limited set of real-life projects, we started a research project in 2005 that aims at the validation of various earned value based

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forecasting methods on a very large and diverse set of fictive projects. We performed this research project and aimed at tightening the bridge between academic knowledge and current practice by generalizing case-specific results to a large and diverse set of project settings. Since simulation studies require computer power, in 2007, the Belgian Chapter of the Project Management Institute decided to fund part of the research.

In this article, we test the performance of the three project duration forecasting methods in an objective way by simulating a large dataset containing projects of moderate size and calculating the forecast accuracy of each method. The outline of this manuscript is as follows:

- In section two, the design of the simulation study is presented in detail. The set of fictive projects is presented, and the simulation methodology is briefly outlined.
- In section 3, an overview of the basic results is presented. These results clearly show that the new earned schedule forecasting methods outperform, on average, the existing earned value based predictors.
- In section 4, we give a conclusion and sketch a brief summary of the future articles.

Test Design

In this section, the test design of the simulation study is outlined. The set of simulated projects is described in detail, followed by the presentation of three project duration forecasting methods. In a last subsection, the mathematical approach to measure the forecast accuracy is discussed.

Set of Simulated Projects

The set of projects has been generated under a controlled design by carefully controlling the structure of each project network. The generator RanGen (Vanhoucke et al., 2007; Demeulemeester et al., 2003) generates activity-on-the-node[3] networks with a predefined number of activities between which precedence relations exist. The set of projects in the simulation study contains 4,100 project networks. Each project network has 30 activities but contains a different amount of precedence relations between the activities leading to a wide variety of different network structures.

Each project is simulated by changing the original planned duration for each activity under a controlled design, leading to a final project duration that might differ from its planned duration. Both projects, that finish ahead of schedule and finish with a delay, have been simulated. Each project is the subject of 100 simulation runs to guarantee simulation convergence.

Forecasting Methods

To the best of our knowledge, only three project duration forecasting methods have been presented in literature. In the remainder of this paper, we refer to these methods as the planned value method (Anbari, 2003), the earned duration method (Jacob, 2003), and the earned schedule method (Lipke, 2003). The first two methods rely on the traditional EV metrics (SV and SPI) while the latter makes use of the novel ES metrics (and SV(t) and SPI(t)). We use the abbreviation EAC(t) for time forecasting (similar to the abbreviation EAC — without the t between brackets — for cost forecasting). The simulation study simulates and compares three forecasting methods, each of which can be considered under three scenarios, according to the future expected performance, as given in Table 1.[4] The expected future performance determines the calculations of the project duration forecast and is a choice the project manager has to make depending on the current project situation (EAC(t) with subscripts $PV_{1,2,3}$, $ED_{1,2,3}$ and $ES_{1,2,3}$). If past performance is not a good predictor of future performance, the expected future performance can be done according to the plan. Problems/opportunities of the past will not affect the future, and the remaining work will be done according to plan. If past performance is a good predictor of future performance (realistic!), the expected future per-

[3]Alternatively, one could model a project network as an activity-on-the-arc network where arcs represent the project activities and nodes represent project events to implicitly model the precedence constraints. Since most commercial software use the activity-on-the-node representation, we do not rely on this alternative project network representation.

[4]Details about the mathematical formulas of each method can be found in Vandevoorde and Vanhoucke (2006).

formance is likely to follow the current SPI trend. Problems/opportunities of the past will affect future performance, and the remaining work will be corrected for the observed efficiencies or inefficiencies. If past cost and schedule problems are good indicators for future performance (i.e., cost and schedule management are inseparable), the expected future performance is likely to follow the SCI trend. The SCI = SPI * CPI (schedule cost ratio) is often called the critical ratio index

Forecast Accuracy

The accuracy of the forecast is measured for each project under an early and late performance. During the simulation, the final project duration is forecast by means of the three EAC(t) methods (where each method can be calculated according to three scenarios, see Table 1). After the simulation run, the final real project duration is compared with the average forecast value (i.e., the average of all EAC(t) values measured during the life of the project). More precisely, the accuracy is measured as the average of the absolute values of all deviations between the various forecasts measured along the life of the project and the real project duration. This accuracy is expressed as a percentage deviation, with lower values denoting a better forecast accuracy.

Computational Experiments

In this section, the main results of the simulation study are presented. The first part compares the overall accuracy of early and late projects for the three forecasting methods under the three scenarios (see Table 1). The second part measures the accuracy along the stages of completion for each project.

Overall Accuracy of the Three Methods

Figure 1 shows the average overall forecast accuracy as the average percentage deviation between the planned duration and the average predicted duration over all review periods (see earlier) of the three methods for early and late projects (note that the EAC(t) measures have been abbreviated to PV, ED, and ES).

The figure clearly reveals that the earned schedule method outperforms, on average, the two other forecasting methods (planned value method and earned duration method), both for projects that finish ahead of schedule and projects with a delay. Moreover, the figure also shows that the forecasting method that assumes that the expected future performance follows the current SPI or SPI(t) trend (i.e., $EAC(t)_{ES2}$) outperforms the other methods.

Accuracy Along the Stages of Completion

In this part, the forecast accuracy is reported along the stage of the project completion for projects ahead of schedule or for projects with a delay. The early stage is defined as the first 30% of the project completion, the middle stage is defined as the interval between 30% and 70% completion, and the late stage equals the last 30% completion of the project. Table 2 displays the accuracy for the early, middle, and late stage of the project for all forecasting methods.

The results from the table confirm the previously found results and show that the earned schedule method outperforms, on average, the other forecasting methods. The results also illustrate the quirky behavior of the SPI indicator (used in the planned value and earned duration methods) at the late stage of the project. Indeed, the late stage forecast accuracy is much better for the ES method compared to the PV and ED methods. The SPI(t) indicator of the earned schedule method is developed to overcome this quirky behavior, leading to an improved forecast accuracy at the end of the project.

Table 1: Forecasting measures (Source: Vandevoorde and Vanhoucke (2006))

	Forecasting method		
Expected future performance	**Anbari (2003)**	**Jacob (2003)**	**Lipke (2003)**
According to plan	$EAC(t)_{PV1}$	$EAC(t)_{ED1}$	$EAC(t)_{ES1}$
Follows current SPI or SPI(t) trend	$EAC(t)_{PV2}$ -	$EAC(t)_{ED2}$ -	- $EAC(t)_{ES2}$
Follows current SCI or SCI(t) trend	$EAC(t)_{PV3}$ -	$EAC(t)_{ED3}$ -	- $EAC(t)_{ES3}$
	= **Planned Value**	= **Earned Duration**	= **Earned Schedule**

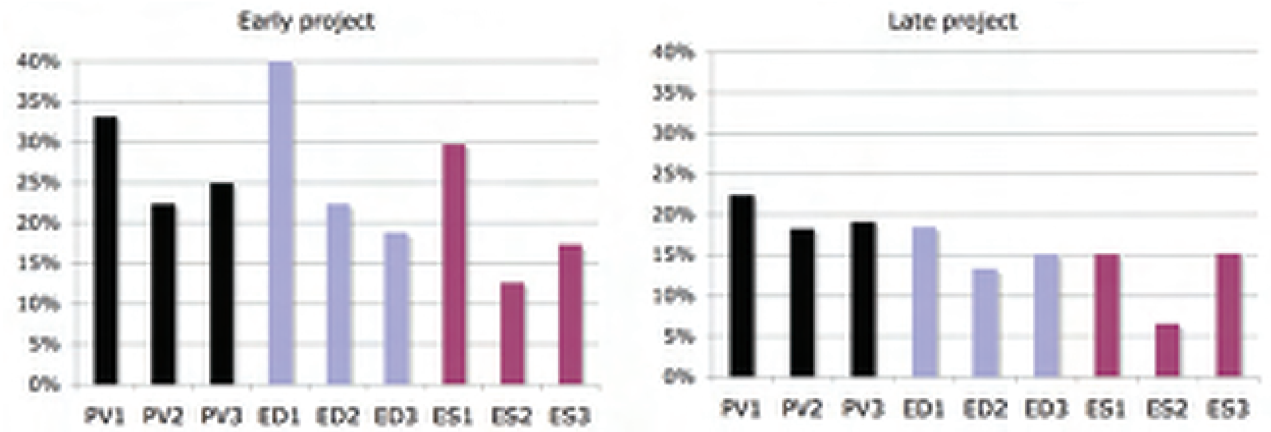

Figure 1: Overall forecast accuracy of the three forecasting methods

Conclusions and Future Work

In this paper, a brief overview of our simulation study (Vanhoucke and Vandevoorde, 2007) has been presented that compares a recently introduced earned schedule project duration forecasting technique with the more traditional earned value based forecasting metrics. This article presents basic results of the simulation study, while other, more detailed results will be presented in later articles. The main results are that the earned schedule metrics outperform, on the average, both the planned value method (Anbari, 2003) and earned duration (Jacob, 2003) methods. Moreover, the studies reveal that the earned schedule method is more reliable in all stages (early stage, middle stage, and late stage) of the project life cycle.

Our next article will elaborate on the forecast accuracy of earned value predictors and investigate whether there is a difference in accuracy between critical and non-critical activities. Meanwhile, the academic research remains ongoing and focuses on the simulation of the p-factor study of Lipke (2004). Details can be expected in the beginning of 2008.

In the somewhat more distant future, a new book on earned schedule management will be published where algorithmic details and case studies, and many more issues will be discussed in detail. At the same time, a novel software package will be launched that enables earned value/schedule project tracking and the simulation study presented in the current manuscript. This project is in the middle of the development phase. More details will follow in a later article or will soon be accessible on www.or-as.be.

Table 2: Forecast accuracy along the completion stage of the project

		Early stage	Middle stage	Late stage
Early project	$EAC(t)_{PV1}$	53.32%	38.72%	23.13%
	$EAC(t)_{PV2}$	26.12%	20.79%	19.45%
	$EAC(t)_{PV3}$	36.53%	31.29%	26.52%
	$EAC(t)_{ED1}$	58.20%	47.64%	32.41%
	$EAC(t)_{ED2}$	26.12%	20.79%	19.45%
	$EAC(t)_{ED3}$	34.12%	21.61%	11.74%
	$EAC(t)_{ES1}$	56.47%	42.09%	15.22%
	$EAC(t)_{ES2}$	23.90%	15.06%	6.32%
	$EAC(t)_{ES3}$	38.58%	26.28%	9.35%
Late project	$EAC(t)_{PV1}$	25.97%	18.57%	22.97%
	$EAC(t)_{PV2}$	16.08%	12.30%	21.50%
	$EAC(t)_{PV3}$	30.58%	26.99%	10.03%
	$EAC(t)_{ED1}$	27.39%	20.95%	12.40%
	$EAC(t)_{ED2}$	16.08%	12.31%	10.69%
	$EAC(t)_{ED3}$	27.83%	16.53%	7.80%
	$EAC(t)_{ES1}$	27.09%	19.32%	7.05%
	$EAC(t)_{ES2}$	11.60%	6.62%	3.01%
	$EAC(t)_{ES3}$	31.16%	22.35%	8.42%

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